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RELEASED ASHLAR—A PROBLEM IN ORNAMENTATION AND BUILDING CONSTRUCTION.

BY JOHN COTTER PELTON, MEMBER OF THE TECHNICAL SOCIETY OF THE PACIFIC COAST.

[Read before the Society, December 6, 1895.*]

THIS paper is prepared for the purpose of calling your attention not to any particular form of released ashlar construction, but to the subject of released ashlar construction in its broad application to modern structures.

I feel that it is a subject in touch with modern thought and in line with modern constructional progress. I think that in our progress toward the attainment in effect of a superior result, with a minimum of material, this form of construction may play some part.

I would not pull down the monumental memories of Greece and Rome, but I may ask of you, shall we ever again build a Parthenon or a Colosseum? Are not our investigations now in another and different field? Are they not influenced and governed by totally different exigencies and sentiments?

The architectural world of 1895 is not the world before Christ, nor is the world of to-day the world of to-morrow.

The day does not close, but sees, at some fellow-craftsman's hands, he improvement of a theory or the development of a better one.

* Manuscript received January 26, 1895.—*Secretary, Ass'n of Eng. Socs.*

I feel the sentiment in each subtle line of Grecian grace. The fragments of the Acropolis hill tell me of the men who brought their work to such perfection, and of the spirit which was THEIR influence, under which they lived and strove, but it was not the spirit which moves us of to-day.

I will confess to a profound awe in the study of the Parthenon or the Colosseum, as structures, but still I do not think, while engaged in that study, that any of us look forward to a commission to build a Parthenon or a Colosseum.

The pyramids are inspiring. That simple, blind piling up of stone upon stone was an accomplishment so herculean as to try the patience in the development of a tenable theory of construction, a work costing years of time, and the lives of thousands of human beings, and all for the construction of a receiving vault of limited size for the security of the remains or the treasures of a king. I cannot doubt that, for purposes of safe storage, the Greeks would choose, to-day, a modern safe deposit vault in preference to any of their temples.

But it is quite idle to make these comparisons. Let us ask each other, not, are we rebuilding pyramids, or Parthenons? but, are we building to-day even as our masters built? Are we building just as we were ourselves building, only a few years ago?

I hardly believe that any of us would confess that ours is the only craft not in that procession which moves slowly but as surely as the star of empire, with that profound sentiment, that unconquerable purpose, *the improvement of the condition of man.* But rather, may we not claim that through all ages, in architectural development will be found a certain and positive index of the condition of religions, of social and commercial life?

The impellant idea which I have had in mind in the perfection of a method of safe construction of a thin ashlar facing for a structural wall, is the minimum use of the more *costly and beautiful materials, stone and marble;* an idea originating possibly in the pyramids, and developing in the Latin countries early in the Christian era. I have hardly had time or opportunity to trace the earlier applications of the idea. We need, I think, go no further back than the pyramids of Cheops, where we may find the most positive and elaborate evidence in heavy ashlar of black granite on the exterior, and of more rare and beautiful colored granites and porphyry in the interior passages. Nor is it necessary to take up time in such an effort. We know that in the old world such ashlar is seen on every hand in many forms and degrees of thickness, frequently in the form of a mere veneering of inch marble.

St. Mark's, in Venice, from sill to spires, is of rare and beautiful marbles; and I am sure no question will be raised as to its permanency,

although the method of attachment was most simple, consisting only in wiring and cementing. I feel rather that a question would have been raised by this economical race of people as to the burying of costly stone in walls of unnecessary thickness.

All along the Grand Canal, in Venice, we find veneer construction from one to three inches in thickness, of marble and sandstone in palaces, dating back as far as the eighth century.

The Milan Cathedral may be mentioned as a notable example of marble veneering. In parts of the building, marble was used in heavy structural form, while later, from economical reasons, veneer construction on brick walls was substituted, and the building so completed, and this where marble is cheaper than in any other part of the world.

Passing now the economical use of costly or choice material, I will attempt the substantiation of my conviction of the superiority of the released ashlar form of construction. To make this clearer, let us separate the necessary elements of a wall—strength, rigidity, fire resistance and architectural character.

It seems clear that it may be demonstrated that a wall of proper construction, not connected structurally with the ashlar facing, is more perfect than a wall of composite character, say than a wall of bonded brick and stone masonry; at least where there is limitation of cost and of occupied space.

I trust I shall not be severely criticised when I claim that a wall of given dimensions, carried to a considerable height, is a more reliable and certain construction if of solid brickwork of good character, than if of bonded brickwork and stone. This difference is due to the wide difference between the crushing resistance of brick alone or of stone alone, on the one hand, and that of brick and stone bonded together on the other hand; and, also, by reason of unevenness in settlement due to the greater number of mortar joints in the brickwork than in the stonework. We may take the crushing resistance of brickwork at from 300 to 1,000 pounds per square inch, and that of the ordinary sandstones of this coast as varying, according to various authorities, from 1,500 to 10,000 pounds per square inch. I submit to you the difficulty of a satisfactory adjustment of this difference of strength in a wall which is built as a unit, and that, if the adjustment is not perfect, there can be no integrity in the wall.

I will not limit the comparison to the crushing resistance, but will risk criticism again in claiming, for a wall of uniform material, a greater degree of strength and permanence from any point of calculation.

The California Hotel and Theater Building is an illustration to which I will refer, with some diffidence, however, as I realize that there must be several views and differing versions to account for its erroneous

construction, but from no standpoint can the failure be considered as pardonable. There is error in calculation, error in choice of material, error in adjustment of incumbent weight, or error in workmanship by stone-cutter or by setter; and, although I do not suggest the shirking of either question when circumstances demand such a structure, I do, without hesitation, call your attention to the much more simple solution of each and every one of these features in the use of a wall of uniform material, *i. e.*, of brickwork with a released facing.

In the question of rigidity in emergency, such as vibration caused by heavy traffic, or the more severe strain imposed by the shock of an earthquake, I believe that investigation will again reveal the superiority of this construction.

The settlement of a wall of brick or of masonry is one of the vital considerations, if not the most vital, in such work. This natural settlement or contraction in average work has been estimated to be sometimes as much as $\frac{3}{4}$ of an inch in 10 feet of height, and every engineer, architect, superintendent of construction and builder knows the care, contingent upon such settlement, which must be exercised in the construction of the parts while the work is in progress. Even in buildings of moderate height this settlement may be of much moment; and, if it exists, it must be provided for somewhere or somehow. It can not be ignored. It must be traced in its effects, or failure in some part of the structure is certain. If this be applied to a brick wall of even and defined strength it is in itself serious; if applied to a wall of two different materials of differing strengths, it becomes worthy of most careful consideration. It must be admitted that the releasement of the facing absolutely solves this problem. The walls are carried to their full heights, almost the entire weight of the building is imposed, and the settlement or contraction has taken place, before the ashlar is set in place.

The question of the prevention of dampness in walls of buildings of brick, or of brick and masonry, has received your attention too often to require more than a brief mention. I will confess to a surprise in reading but recently of the use of hollow bricks in the walls of the Parthenon, built 430 years before Christ. The reflection, therefore, that allowing the absorption of a common brick to be one pint of water, the walls of the Mills Building, in this city, might, if exposed on all sides through their whole length, absorb no less than 420,000 gallons of water, or 1,680 tons, emboldens me to claim the overcoming of this fault of an ordinary wall as a third feature of advantage. Sandstone of the average density is hardly less absorbent than brick.

I will ask here whether, in the exact computation of the parts and functions of the parts of a modern structure, this additional weight should be ignored? I fear it often is. We are all familar with a

number of expedients, of forms of construction, devices in wall anchors, etc., designed to release the outer 4-inch facing of a brick wall, and for the purpose only of protecting the inner or structural wall from the accumulation or absorption of dampness; and I believe that within a few years this form of construction has been recognized as the most successful, in fact the only form certain of the accomplishment of the purpose.

I cannot but feel convinced that, by the provision of an air space, much will be accomplished in the equalization of the temperature, not only in the avoidance of the dangerous dampness, but in protection against the effects of changes of temperature in the outside air. I submit that if this can be admitted, it is a consideration of importance in climates demanding the heating of buildings at great expense.

As to the question of fire-resisting qualities, I think I can again demonstrate superiority due to the space filled with air between the structural wall and the ashlar facing, and suggest that, until the outer facing has been destroyed and fallen off, the wall itself remains cool and unaffected by the heat. With reference to the facing as a protection against fire, certainly much depends upon the selection of a material of superior fire-resisting quality.

I may suggest, in the event of a partial destruction by fire of a building so constructed, the possibility of making repairs without the total demolition of the wall, and here I will pass the reviews of the practical structural functions and will conclude with a few words on the resultant features of rapidity of construction and economy of property area.

No general estimates can be made of either of these features, or of the amount of time which may be saved, or of the saving of space occupied by walls. Such estimates require special comparison. That such construction may be rapidly prosecuted is evident, the walls being carried to their full height without interruption and without delay in the preparation of the material for the façade, in which, whether of brick and terra-cotta, or of brick and stone, may usually be found the cause of delay, consequent upon its more elaborate character and the slower process of ordinary construction. The building being under roof and inclosed, the prosecution of the work of the interior is made entirely independent and may be begun at a much earlier period.

Time is usually of sufficient importance to be considered in any business undertaking. In a building enterprise the first question of importance, after that of cost, is the time which must be given to the work of construction, and many plans and methods are taken advantage of to facilitate progress and to hasten the occupation of the building and the opening of the rent roll.

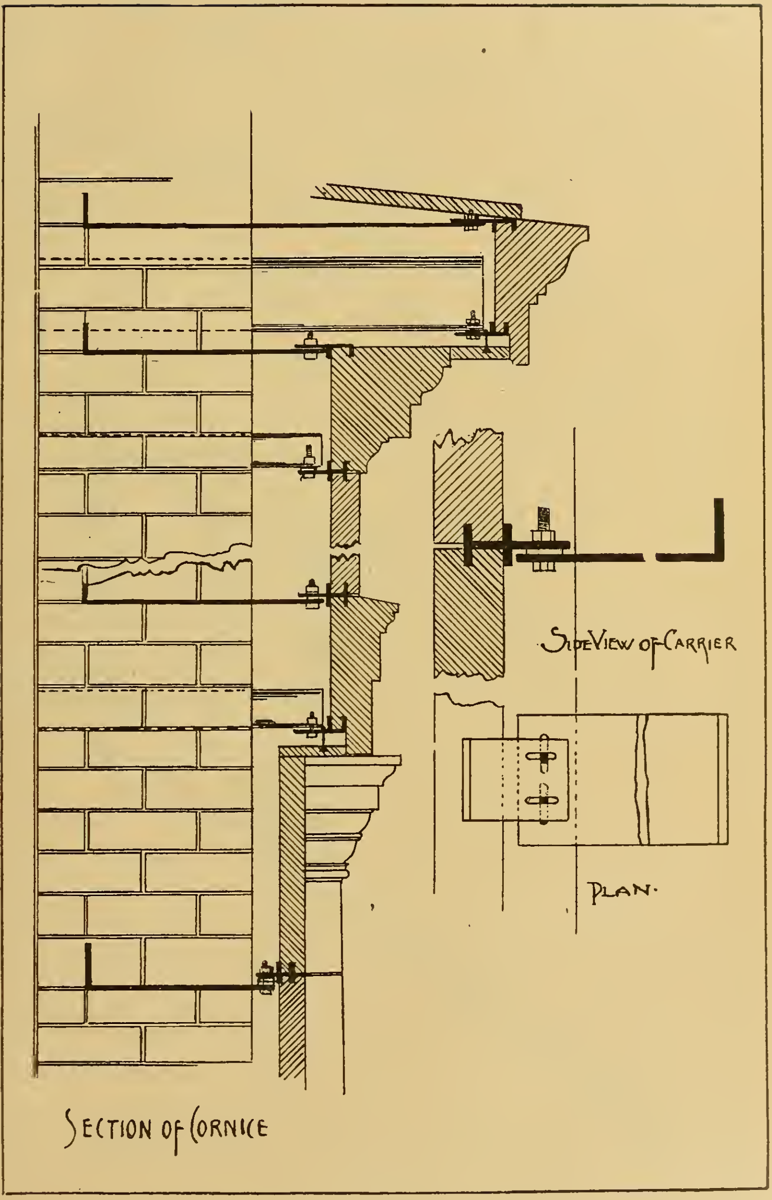
The loss from the area of land, in space occupied by the walls, I do not believe is always appreciated. I am quite sure it would startle the owners of some buildings of even recent date. The Mills Building, in this city, loses, in its walls, 12 per cent. of the lot area. The Crocker Building loses 18 per cent. and the Chronicle loses 21 per cent. This represents a loss in income, and any saving in such loss means just so much increase in the income.

The first building to which I applied a marble facing was built on California Street, near Devisadero Street, in this city, for Mr. John I. abin, some four years ago. This was a wooden building, and was

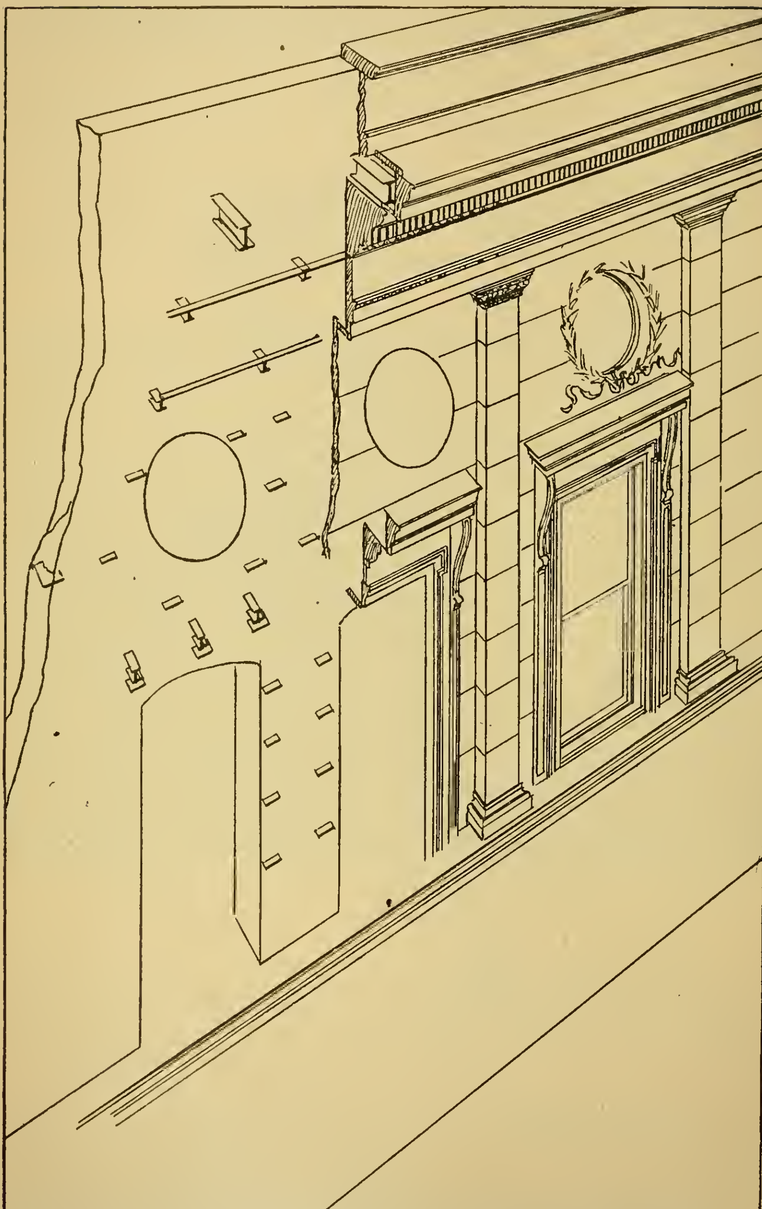
Stockton Library Building, San Francisco.

faced to a height of about 10 feet, this height representing about the extent of my confidence in the safety of 2-inch marble. I could figure to do much better, but did not feel quite prepared to undertake a greater height.

The next occasion presented itself in the Telephone Building at Los Angeles. The character of the design called for uniformity of material. The height was about 30 feet, and there was, with the limit of my first experience (10 feet) in mind, developed the idea of dividing this height of 30 feet into three sections, and supporting the weight of each section independently, *i. e.*, transmitting it to the wall. This may be called the first step in this method of ashlar construction, *i. e.*, the interruption of



STOCKTON LIBRARY BUILDING, SAN FRANCISCO.—DETAILS.



Stockton Library Building, San Francisco.—Section of Front.

the accumulation of the weight. The walls of this building were built, the carriers were set, and the setting of the marble had progressed to the height of the first interruption or carrier, when it was discovered that the variation of these carriers from the proper measurements was so great, and the alignment so irregular, as almost to cause an abandonment of the proposed façade, and this was with difficulty overcome. Here came in the attachment of a second and separable bracket or shelf, with means of adjustment to this irregularity of setting and alignment.

The construction of the marble Library Building at Stockton, California, with a frontage of 210 feet, was then undertaken and carried to a successful issue.

I trust I am not over-confident in saying that this piece of work has demonstrated the feasibility of the constructional principles here advocated, and that an examination of its details will substantiate the claims which I have made for the released system of ashlar construction.

Let us now look for objections; if this is *not* a proper form of construction, there must be clear and tenable reasons, readily stated.

Let us first look for these objections from an artistic or æsthetic standpoint. I have sought earnestly, and am unable to find, an æsthetic law of thickness. I find nothing to justify the term "veneering."

I have never heard an artistic comment upon the thickness or the amount of paint upon an artist's canvass. It is the expression, the character or the sentiment, which appeals to us. In fact, I cannot find in the world of art, or in the æsthetic history of architecture, anything about the thickness of such facings. To be more practical, I have never heard the term veneering applied, except by the ignorant, to the architectural facing of 4 inches of pressed brick in the usual form.

Now, from a constructional standpoint, I am unable to figure out a practical defect which cannot be provided for. I will state two which have been brought to my attention, which have been certainly worthy of the most careful study and investigation, and to which I am prepared to make answer; but upon these points, I feel that much more can be said, and I trust that if this subject seems to you to be of interest, or if the perfection of such a system of construction is of value, some discussion of these questions may ensue.

These questions are: the possibility of leakage through the joints, and the grinding tendency caused by vibration in a tall structure.

The question of leakage, I think, may be answered by proper attention to the workmanship. I have not heard this question raised against the use of a facing of pressed brick, having a multiplicity of joints. Why, then, should it be raised against a construction by which this very possibility is reduced five-fold. Still, it has been suggested by Mr. G.

W. Percy, in his report to the Harbor Commission, that, should such danger arise through accident or careless workmanship, means may be provided, in the space behind the facing, to care for such seepage.

In the consideration of the question of the tendency to grinding, it may be observed that it must be a very tall structure in which this action would take place; but believing that here also the result will be found satisfactory, I am prepared to allow to it all the importance which the most careful and technical practitioner may think necessary. In fact, does not the consideration of this very question result in favor of the interruption of the facing frequently in the height of such a building and thus lead to another finding in favor of the method? As to the thickness of the facing and the frequency of the interruption, I may say that one balances the other; for, as the facing increases in thickness, the interruptions should be made at more frequent intervals.

As to the forms of the carriers or anchors, this, of course, depends upon their position, or upon the duty which they must perform, and varies constantly according to the architectural character of the façade, etc.

Something might be said of the adaptability of this method of construction to various designs, but it seems unnecessary; for, although familiarity with this form of construction might lead to more simple and readily applied design or style, it is but a matter of more or less study to make its application satisfactory in any example.

I may state that in the construction of the Stockton Library Building, where the Grecian Ionic style was used, no detail was sacrificed in the application of the construction. The style was fully carried out in all its parts and in every detail.

The respective projections are provided for, simply by greater strength in the parts.

In the treatment of exposed corners, reference may be again made to the Library Building and to the Telephone Company's building, in no part of which structures is the thickness of the material evident, and how much more readily this may be effected in the freer Romanesque or Renaissance details, need only be suggested.

I feel that in the application of this form of construction to a modern building with steel framing, there is possible a most perfect achievement, attaining a degree of perfection beyond any form now in use, *i. e.*, the strength of the structure may be secured in the steel frame, a minimum of material being used for the protection of this frame from fire, and a minimum of material being required for the facing.

DISCUSSION.

President Dickie.—While we have had very little architectural matter to discuss in this Society, the subject is exceedingly interesting, not only from an architectural, but also from an engineering point of view. I trust that it will be fully discussed, and that no point concerning it will be left in the dark.

I can conceive of many advantages that this construction presents, especially in our State, where we have so many kinds of building stone, and such a variety of marble to be utilized.

One point which was not brought out in the paper, and which I thought of while it was being read, is, that the facing work might be prepared in a factory, jointed and put together, polished and finished, and taken to the building complete, and ready for erection, as is now done with woodwork.

Mr. H. T. Bestor.—It will be interesting if Mr. Pelton will take the blocks of marble and the iron anchors that he has exhibited here, and show us how they are put together, and also explain his facilities for alignment of the blocks.

Mr. Pelton.—What we know we have learned through the correction of errors. For instance: I made a mistake in trying to secure a proper and correct placement of fixed carriers in the Telephone Building at Los Angeles. When we got up to the point of second interruption, the anchors were not there; they were about a quarter of an inch out of their proper position, and I believe some of them were three-quarters of an inch out. At first, that defect seemed almost insuperable. It gave rise to the use of an adjustable or secondary shelf. The first shelf is built into the wall while in course of construction, in the joint next below the level required to meet the course of stone. Then, when the ashlar is to be set, a secondary bracket or shelf-rest is put on, and adjusted by means of washers to the exact position required (the bolt is then set). The lower slab is let in before the bracket is fixed. Then comes the next course, and the thickness of the anchor represents the thickness of the joint. The joint is then filled in with cement.

With a fixed carrier, constant and careful attention had to be given to the plumbing of the face. In any masonry construction, much time is consumed in the exact setting. I found that many pieces of stone had to come back to the ground and be trimmed over again. I think Mr. Dickie has made an excellent suggestion. It would certainly secure a much more perfect and much more rapid and effective method of construction to have everything come from the shop or mill quite ready for setting.

The anchorage of the blocks is made in a slot cut in the edge of the block, to receive the forward lug of the anchor.

The form of anchor referred to this evening is that required for a thin wall-covering; that is to say, for a thickness of two inches. When we come to projections we get into a field requiring a little calculation. We have to consider the weight to be carried, the form of the anchor must be varied, and they must be made heavier.

The width of the air space is a matter of choice. I think a space of two inches as good as a foot.

As to the effect of contraction and expansion due to great variations in temperature, as in the case of a fire across the street, I may say that I have thus far confined myself to marble facing in connection with this construction, and marble will stand more heat than any other stone. In case of a fire it would have to burn to lime before it would fall. I think the air space would keep the walls cool, and that we need not expect much difficulty from this source. As stated in my paper, in case of destruction by fire, or possibly by some other cause, of a section of this construction on a building, the means of the reapplication of it is still there, as the wall itself and the anchors might not be injured.

Q. Would that wall have as much stiffness against the wind as a solid wall?

A. The element of strength is represented by the wall; the ashlar facing is not a part of the construction.

Upon the question of vibration I should like to hear all that can be said. I believe it is the most important question that has been brought out. The question of leakage, as I said before, I think may be overcome by careful workmanship. Mr. Reid has suggested that it is possible, in a very tall structure, to start such a vibration as to create a grinding tendency. That may be so, but if there should be a grinding tendency, these very interruptions will stop it. If the grinding is established, I hope also that I may be sustained in the proposition that it has been overcome.

As to the effect from the heat of the sun, I do not think the expansion, followed by contraction, would cause any trouble in brick or stone walls.

Mr. Dickie.—We have large amounts of metal in all kinds of walls nowadays, and there does not appear to be any difficulty or danger from expansion, whether it be equal or unequal.

Q. Are not anchors made very light for holding walls together and holding pieces together?

Mr. Dickie.—We have walls with steel girders built in with them, the wall being simply a panel, and the expansion does not seem to open any joints in connection with them.

In listening to this paper it has occurred to me that the fastenings adopted are rather crude. Suppose we had a brick wall, and were intending to put on it a face of another kind of material, say of marble.

I would put my anchors into vertical lines at such intervals as was most convenient, allowing some of them to project farther than others, according to the shape of the outside piece; and on these anchors I would place a strip of metal, say a 2½-inch bar, which would take the form of the projections intended. This would be put in the wall, and the face would be put on afterwards, plumbed and fastened. And then, for seams, I would simply have a little channel-bar running along horizontally and fastened to a shelf, and this would break the joint so that water could not get in. By that means the whole structure can be completed before the bars are put on.

If it is necessary to drill holes in the 2½ by ½-inch strips, they can be drilled.

Mr. Bestor.—In St. Louis, in 1859, we put anchors into the brickwork, and the brickwork would settle, while the stonework would not settle to the same extent, and finally the stone slabs would be thrown out of line. There will always be a settling of the brickwork for some time after laying, and that will crowd the channel iron chains very closely on the stone, thus the stone may be so closely pressed as to break the inner lip. The use of the iron anchors as proposed by Mr. Pelton appears to have many points in its favor.

While the Bank of California was building, the joints of the stone were raked out to a depth of ¾ inch, and the pointing was done soon after the brickwork was finished. The first earthquake thereafter, the stone in many places broke away from the joints. If the stone had been put on so as to have had some support from anchors, as proposed, it would have helped very much to protect the joints.

Mr. Dickie.—As I said before, this method seems to be very crude. A hole has to be cut in the stone to take the lug; but in the method I suggest, the stone would be put through a machine and cut out just as pieces of flooring are; the blocks would rest on the iron, and when these two faces came together on the outside, it would have a strengthening effect.

Mr. Pelton.—One of the defects I brought out was these fixed points. I am trying to avoid them.

Mr. Dickie.—In the case I present they would not require to be fixed.

Mr. Pelton.—Something has to be fixed.

Mr. Frank Shea.—Instead of the idea suggested by the President this seems to me the proper way of construction, and that accurate workmanship could be obtained by bringing anchors from the steel frame to carry this outer covering. This would do away with the many troubles that arise in other methods of adjusting the blocks afterwards. I think it is poor policy, in the light of modern thought, to build heavy

walls of masonry, and that it is better to have a steel framework and a rigid curtain wall, and then we have an accurate line for the placing of the different parts.

Mr. Dickie.—I have no doubt that this method of construction, should it prevail, will lead to the abandonment of both stone or brick in outside walls altogether. I have no doubt about that. I am rather astonished that architects talk about stone and brick for heavy walls. Why not have walls that are bolted and riveted and lapped, the same as we build up a ship or boiler? Then the ornamentation can be put on outside of that, as you wish. Our architects are sleeping; they do not think about those things. Some day some of us boiler-makers and ship-builders will build the houses, and we will get the architects to come and put on the adornments after the box is put up.

Mr. Frank Shea.—The architects are not sleeping in that regard. The Eastern structures are in line with the suggestions that the President has made, and they are not at all new to the world. Our greatest structures in the East are made of a steel frame, and the covering has almost resolved itself down to a covering of boiler plates. The idea is to do away with as much wall surface as possible. There are buildings, with walls 4 to 8 inches in thickness, that run up to 15 and 20 stories in height.

I think this is a happy time for the discussion of this subject, because the architects now look to the engineers with the greatest of interest, and as co-partners and co-laborers in the work of construction. The idea of heavy solid walls is being abandoned, and your idea of building, Mr. President, is being adopted in its truest sense throughout the country. We have many buildings of steel frame, with a covering only of cast iron of from $\frac{1}{2}$ to $\frac{3}{4}$ inch thickness.

Mr. Dickie.—This method of construction is not very different from our old method of our cast-iron ornamented fronts such as are seen in some buildings in this city. The outer part is carried up in very much the same way as this method, only one is a $\frac{1}{2}$ inch iron casting, while the other is 2 inch marble.

Mr. Bestor.—The facing of the Safe Deposit Building in this city is of stone and the pilasters are stone bonded into the brickwork, but the old cornices (which have lately been taken down) were made of galvanized iron. A portion of the Nevada Block is of cast iron. The columns and window frames were of cast iron. The London and San Francisco Bank has a cast-iron sheathing. The basement and first story is cast iron.

Mr. Pelton.—The ideas brought out this evening all tend to the minimum use of material. This, with a maximum degree of strength, perfect protection against fire, and a façade still expressive of architectural grace and dignity, I feel, makes up a worthy combination.

OBSERVATIONS OF ENGLISH RAILWAY PRACTICE, WITH SOME ACCOUNT OF THE FIFTH SESSION OF THE INTERNATIONAL RAILWAY CONGRESS.

By George B. Leighton, Member of the Engineers' Club of St. Louis.

[Read before the Club, January 8, 1896.*]

It may be said of the railway as well as of the common law, that they are the creation—the child—of the Anglo-Saxon mind, as of political and religious freedom. The important steps in the development of these great economic and social forces and conditions, enabling men to live together in the highest development of civilization, have been brought forth by the English mind. The locomotive, the steel rail and the power brake, are the inventions of Englishmen or Americans.

An American, however, in order to understand the real workings of railways in England, must familiarize himself thoroughly with the conditions that exist there, largely the results of race and of national characteristics. The conditions affecting the traffic working of English railways are materially different from those in the United States. Although the mileage in the United Kingdom is about one-tenth that in the United States, the number of tons handled per annum is nearly one-half those handled here. In Great Britain, small shipments, to be carried to one of many stations, are presented to railways. These, owing to the proportionate relation between the actual haul and terminal expenses, go by themselves. In this country, we should place many of them in the same car, and reload into a local car in transit. In England, this transfer would necessitate great delays. Again, English rates are based on the ton as a unit, where ours are based on the carload. The average carload in England is not over three tons, but trains are moved with great promptness. Even some freight trains are scheduled at fifty miles an hour.†

Again, in passenger traffic, with us it is exceptional that a full train can be expected from one terminal to another without intermediate stops. Most of our trains are obliged to do somewhat of a local business. In England the numerous cities, comparatively but a few miles apart, furnish a traffic equal to that between New York, Philadelphia and Washington. Scotch and Irish railways more closely resemble those in

* Manuscript received January 27, 1896.—*Secretary, Ass'n of Eng. Socs.*

† Ackworth—The Railways of England, p. 101.

our country, many of them having but a single track. There are in the United Kingdom some 20,000 miles of railway, of which half have additional one or more tracks.

I shall endeavor to describe some of the salient points, which to my mind are of interest to a close observer of English railway practice, but shall not attempt to describe well-known characteristics. I will devote some words to the International Railway Congress, which held its fifth session in London last June, closing with a few remarks on the delightful social gatherings which took place on that occasion.

In observing a railway and its workings, it is natural to begin with the line and its construction.

The topography of England is of a rolling character—in places almost mountainous. The early railway builders so firmly believed that an engine and a car could not operate successfully on short curves or on heavy grades that the early lines were constructed on long planes and with curves of large radius adapted to the rolling stock, all of which had rigid wheel base. This involved the crossing of wide valleys by means of high bridges and the construction of tunnels. Hence the (capital) cost was necessarily great. Unfortunately the clearance allowed by the early works was small in width and height. These are general characteristics of the English trunk lines. But there are heavy grades and sharp curves in England, and more especially in Scotland and Ireland. Even on the great trunk lines, upon which the remarkable runs of the past summer have been made, there is at one place, known as Beattock Bank, a distance of ten miles with a continuous grade of one and a half per cent. The summit of this line is ten hundred feet above the sea. In the early construction of lines in England, as with us, sharp grades were worked by stationary engines. There is one grade on the Birmingham and Gloucester, now a portion of the Midland Railway, which, as early as 1838, was worked by American locomotives, on account of their ability to do hill work.* On the Lancashire and Yorkshire, grades of upwards of three per cent. are worked in freight service, but not on the main line.

A prominent characteristic of the English railways is, that they have been built to endure. The substructure of English lines is solid. The cuttings are well sloped and well drained. Where possible, masonry viaducts are used. The bridges have enormous weight and strength. Single track construction has been carried out on this same general scale. Important stations are of brick or stone, well lit by glass roofs.

From the early location of many of these lines, it is easy to infer that the engineers were more or less limited in their choice of location,

* Williams—History of the Midland Railway, p. 76.

that is, but little lateral variation in the right of way was permissible. At that time, the owners of estates and boroughs did not want the unsightly locomotive to cross them. The consequence of these conditions was that enormous prices were paid for rights of way and leases. To this day the North Eastern Railway is paying nearly a quarter of a million dollars annually for leases of rights of way; they would like to change their line and acquire the ownership, saing this great expense. However, the English landlord, at first desiring to be compensated for the injury to his property by the trespass of the locomotive, is now unwilling to lose this source of revenue, having decided that the locomotive is not so bad after all. A Bill to enable this company to so change its right of way has been defeated by the landed interests at several sessions of Parliament.

So far the American is pleased with the construction of the English lines, and wishes that he might have as good here. But, pausing to notice the track, he does not feel anything like the same degree of envy. The universal track construction in England is that of the double-headed rail of 75 to 90 pounds per yard; tie chair with ten ties (Baltic fir, generally creosoted) to a 30-foot rail, 5 inches in thickness and 10 inches on its face. In Ireland there is a considerable amount of "T"-rail. Steel ties, although somewhat extensively tried on the London & Northwestern, have so far not met with success, warranting adoption.

Average English rails appear to be better rails than the average American, but opportunity is not offered to discuss this fact. The joints on English railways are loose, often low, the click being very noticeable, and are not as good as on most trunk lines in America. The joints are necessarily suspended and have the common fish-plate. Most of the lines in England key their rails with an oak wedge on the outside of the rail, but on the Midland the wedge is on the inside. This lack of uniformity is an instance of the individuality in details of practice, that I shall endeavor to emphasize in these remarks. The Clearing House regulations necessitate uniformity in traffic affairs, and the Board of Trade in other directions, but aside from these there are marked individualities. The London & Northwestern Railway is using in the main line 60-foot rail, but it is alone in this practice.

Our next thought naturally leads us to some consideration of rolling stock. This is tending towards standard types, especially in engines. While the single driver engine is in use on the Great Northern, with apparent satisfaction, the standard English passenger engine of to-day is one 18 x 24 inches inside connected, having four coupled drivers, and a bogie or common truck leading, and a deep copper fire-box. On the Northwestern, and following it in many respects, the Lancashire & Yorkshire, a truck with a radial axle-box is substituted for the common

four-wheel bogie truck. The weight of the average English express engine alone is about 45 tons, of which 30 tons are on the drivers. This gives an approximate weight on each driver of about 7½ tons, which is not so much less than on many of our passenger engines. When there is taken into account with this the immense traffic, it will be seen that the English track has a considerable work to sustain.*

Freight engines are six-coupled without trucks, their weights being often upwards of 50 tons. There is a type of engine in use in England designed for short runs under fifty miles having side tanks. This engine runs equally well in either direction. Boilers are straight.

On some English lines the Ramsbottom track-tank is in use. The advantage of this in passenger service is already appreciated by American lines, but the point seems to escape notice that in handling freight on a busy line there is much to be gained by this device. Freight trains run from Crewe to London, a distance of upwards of one hundred and fifty miles, without stopping for water. The use of the track-tank allows the use of smaller and lighter tenders. The standard tender of the London & Northwestern goods engine is only 1,800 gallons, but on this point again English practice is not uniform. The Great Northern Railway, being part of the East Coast line to Scotland (one of the lines making the fast runs), does not use the trank tank, and is thereby forced to carry a tender of large proportions and great weight.† There is a lack of uniformity in locomotive working as to the position of the runner. The London & Northwestern, and again on the Lancashire & Yorkshire, whose Locomotive Superintendent, Mr. Aspinall, is a pupil of Mr. Webb, place the runner on the left side of the engine. With the exception of these companies, and smaller companies allied to them, the universal practice is for the runner to be placed on the right side. Trains run on the left track. An English runner is a man markedly different in his thoughts and attention from an American runner. On American lines a runner is constantly peering ahead to ascertain and assure himself of the condition of the line, but owing to the universal "absolute" block system in use in England, an engine runner gives but little thought comparatively to this part of his work. When he sees the signal "clear" he assumes the line is clear and gives more attention to the working of his engine than he does to the line while on the block. I must not be misunderstood that he does not look ahead at all, but his chief attention is devoted to the fire and the steam gauge. The working of an English engine on a run may be likened to a popular piece of music in vogue some years ago, which began very faintly, increasing in

* Aspinall—Question VI. International Railway Congress. Express Locomotives.

† The same, p. 35.

intensity and force and then died away. The English engine on a long run, as a rule, has sufficient steam to start its train away, but gradually works up the fire and steam, while towards the end of the run the fire is allowed to die down.* The throttle is worked fully opened.

Returning to rolling stock, the English carriage stock, or coaches, is tending towards several standards for different usage. The second class is disappearing, leaving but a first and third. In through service the vestibule train, with through communication is in general use. But the comfort of these and capacity of freight cars is materially affected by the restriction to 8 feet 6 inches wide and to 13 feet in height.

On the London and Northwestern, the dining cars resemble American construction in much detail. They have six-wheel trucks and are 70 feet all over, weighing upwards of 50 tons.

Can this be said to be light stock? For short run service, the side entrance carriage has many points in its favor, and will no doubt remain the English practice to the end of time. Coaches with six wheels rigid, do not average over 30 feet in length. The bogie truck, however, with four wheels, is coming into use on most lines, and consequently a longer body. Here, again, there is conspicuous lack of uniformity, in that on one of the great systems, the Great Eastern, there is not a bogie truck on the entire system either under an engine or car. The light construction of passenger cars has been disastrous in many accidents. Cleanliness and neatness are especially noticeable in the care of cars and engines.

In freight equipment the cars or wagons are short, and carry as a maximum load, 10 tons per axle, including the weight of the car. The use of the short car has advantages in conditions which pertain in English working—a long car would have but the same load. The system of turntables for shunting in use at freight stations precludes the use of long-bodied freight cars.

In station service the English practice is different from American, and more efficient for English usage. It is questionable if, in some respects, it would not be preferable with us. At passenger stations platforms are on a level with car sill, which, with the side door, enables one to step quickly and safely from the car to the platform. It is noticeable that in two instances where we have in this country the densest traffic, this practice has been resorted to—on the New York and Chicago elevated lines, and on the Illinois Central in the World's Fair traffic and suburban travel. It is a mistake to imagine that trains cannot be unloaded quickly from side doors. We could not profit by the adoption of the side door generally, but is not the tendency to a low platform, now prevalent in this country, a mistaken one? To expect a short per-

* British Locomotives. Coope, Chapter XIX.

son to climb up on a train, or to climb from it, is wrong, and sooner or later it will arouse popular indignation, as it has done in Ohio, where there is a law making the maximum distance between the car-step and the platform 15 inches. Owing to our car-steps, platforms cannot be on a level with the sill, but they can to advantage rise 15 to 18 inches above the rail. The theory would now seem to be that baggage-trucks must be able to run around a station like balls on a billiard table, and that personal comfort must be subservient to this. Passengers can be better relied upon to keep out of the way of trains by offering them a safe and convenient platform, and not tempting them to trespass on the track.

As one alights from an English train in a terminal station, he sees the cabs are alongside the train. He quickly gets his baggage, which is in compartments through the train, and is away in less time with his baggage, than he can be in this country. The assistance of station-porters, ready to assist with one's hand luggage, is most desirable. In connection with the stations, the English railways have established, as a part of their systems, large terminal hotels, which are efficiently managed and highly appreciated by the public. They have also established, in the more picturesque parts of the country, commodious hotels in the nature of resorts.

In freight-station service, there is a conspicuous difference between American and English practice. Generally, English local rates are based on the idea of store-door receipt and delivery, in which case the company conveys the goods to the station by its wagon, and delivers them by wagon to the consignee. This enables the company to have full control of the wagons at the station-yard, and to allow a wagon to remain loaded for some hours, the horses being detached and used on another. From this practice has grown that of collecting the goods during the day, and not attempting to load the cars or trucks until afternoon, then the loading is proceeded with, with great rapidity, the wagons being backed up against the platform, and trains are dispatched promptly and frequently. After midnight, incoming trains arrive in the same station, goods are loaded into the wagons, now empty, which brought in the goods in the early evening, and at daylight horses are brought into requisition and the goods promptly delivered. Several London freight stations have two stories, the underground part being devoted to the loading of cars, and the other to the marshalling of trains, a hydraulic car elevator being used.*

At the Broad Street Station of the London & Northwestern Road, one elevator performed the entire service when I visited it, delivering

* Turner—Question X. International Railway Congress.

a car about once a minute. In the lower story there is a central line, with hydraulic turntables, to which the cars are pulled from short bays by hydraulic capstans, and in this way passed along one after the other in station order, so that as the train appears above the ground it is ready to be dispatched. But, in the Midland Station, in London, the use of the turntables has been abondoned, and the short bay lines feed directly into a load, as we do in this country. This track terminates in an elevator, thence to the line above, as in Broad Street *

No description of English traffic would be complete without some reference to the gravity yard of the London and Northwestern at Edge Hill near Liverpool.† The yard is designed to assemble traffic from the several Liverpool stations, to marshal it and dispatch it way. It is also used to break up trains arriving at Liverpool. But the outward traffic is more than double the inward, consequently, more than half the inward trains are empties. The outward traffic in 1894 was about a million and a quarter tons. Trains of outward traffic are brought from the various docks to the upper end of the yard, where the engine is cut off. The trains are shunted into line and station order by dropping a grade of about one per cent. The arrangement consists of reception lines, leading into a throat, where the grand division is made of traffic going north and south, these in turn feeding into twenty-four sorting sidings, where the trains are arranged in train order, and they drop from there into another group which arranges them in station order. From here, they are dropped again into the main outgoing line five minutes before train time.

The English freight trucks or cars have only a hand brake which consists of a long lever at the side of the car, pressing down two wooden blocks on one pair of wheels. These the operators in the yard use in checking the progress of the car, but in case of emergency, the normal condition of the lines in the yard is such that, if a runaway should occur, it is gripped by a hook which drags a heavy chain coiled in a receptacle. There are six of such devices in the yard. The working of switches within the yard is manual. Trucks are inspected on arrival, but the men are provided with a brake stick, with which they steady a car having a defective brake.

The average number of trains leaving this yard in twenty-four hours is about sixty, and to illustrate the diversity of traffic in England, we are informed that the average departure for London in this yard does not exceed two trains a day and often but one. Then again it is

* Ackworth—Railways of England, p. 103, etc.

† Statements from a Descriptive Circular Specially Prepared for Visit of the International Railway Congress.

to be remembered that there are many stations in London. This again would prohibit full utilization of the large car. The average English load is about three to four tons, where ours is about ten. The average English train load is about one hundred tons, where on our trunk lines it is upwards of two hundred and fifty. About three thousand trucks pass through this daily, the number of men being employed being slightly less than a hundred. English mineral traffic is carried in private cars; the building and maintenance of these is the subject of strict regulations, but even so, they often cause annoyance, not to say accidents.

We cannot dismiss the subject of operation without a word in regard to the fast runs which have been made on two leading English lines during the past summer,—the East Coast line and the West Coast line from London to Aberdeen, the distance by the East Coast line being 523 miles, by the West Coast, 539. Both lines are undulating, having considerable grades of over one per cent. There is an immense tourist travel to Scotland in August, and these trains were run largely as advertisements, the more barbarous practice of rate-cutting having passed out of existence. A former race was carried on in 1888. "The conditions having somewhat changed since then, the two rival lines decided to try their metal again. The chairmen of all the English lines deprecated racing at their annual meetings, which took place in July, but later said, when reminded of this fact, that the other fellow began it. On August 19th, without giving public notice, the East Coast line shortened its time to Aberdeen, but was surprised to find on the first run that the West Coast train had arrived there before it. Though public notice had not been given of the proposed acceleration, it was necessary to notify the Caledonian Company of the time that the East Coast train would pass Kinnabar signal box, sixteen miles from Aberdeen, from which point the two trains run over the same single line. Stealing a march having proved impossible, it only remained to see what could be done by sheer hard running. The East Coast train then excelled its previous record, but found the West Coast had again beaten it. This took place on Tuesday night of this eventful week. On Wednesday the East Coast got its head to the front and ran to Aberdeen, 523 miles in 520 minutes, while the West Coast was fifteen minutes behind. So confident were the East Coast authorities that this last performance could not be beaten, that they immediately put in hand the reconstruction of a most important bridge, which put further high speed on that line out of the question. But they had reckoned without their host. On Thursday night, the West Coast made a final effort and succeeded in reaching Aberdeen, 540 miles, in 520 minutes."* This gives a

* Ackworth—Railroad Gazette, August, 1895.

rate of 63.35 miles per hour, while the record of the recent run on the Lake Shore gives a record of 65.07. The English train weighed 75 tons, the American 150, both exclusive of engine and tender.

In passing it is well to note a word in regard to English signal practice, which it is the general belief of Americans who visited that country this summer, is not as efficient as the best practice here. The absolute block system prevails, the blocks being manually controlled. No electric locking is in use, except on certain lines south of London, where the Sykes system is somewhat used. Electric track circuits seemed unknown. Generally there is no check to a man giving a clear signal when the train is in the block, excepting his feel that he must not. Single lines are worked wholly by the staff or tablet; a runner being obliged to have this staff before he may proceed over a section, but these are often delivered and received at considerable speed.

The New Haven Road in this country is working with success, switches fifteen hundred feet from the tower, by the manual system, and signals two thousand feet, while the practice in England is never to locate a signal more than a thousand feet. The ordinary form of semaphore is in use, but it is pleasing to note that the white light for night signals has been abandoned. Red indicates "stop," green "safety," and no caution signals are in use. If they are not needed with the dense traffic in England, it would seem as if we should be able to avoid their use in this country.

A few words only are necessary about the organization of an English railway. Officials under somewhat different names, perform the duties of officials here. The Board of Directors is large, but it is an active Board, both as whole and through the sub-committees, which are frequently in session with the General Manager,—the General Manager himself carrying out the policy as outlined by the various committees. Inspector is a term frequently met with; it refers to a class of officers constantly on the line investigating the working of all departments and reporting the condition direct to the General Manager. In other words, they enable the General Manager's eye to be in many places at once. It would seem as if on our large systems, they would be of great assistance and relieve the Manager of much detail work now often neglected.

I may here mention two institutions which have an important bearing on the English practice. The one creation is of the railways, the other a medium between the people and the railway, both as to safety and tariffs. The English *Railway Clearing House* handles all the traffic relations between the railways, but does not deal with the public. It was established by Act of Parliament in 1842, being given powers by which it could sue under the name of its Secretary. Each railway and

steamboat in the United Kingdom Company has one representative of the General Committee. No company is forced to assent to any regulations that it does not desire to. The facility by which the auditing of this great traffic of upwards of a thousand million passengers and four hundred thousand million tons of freight annually are handled is interesting. Traffic confined to one road does not go through the Clearing House. The clearing house has an executive board which is in constant session at its headquarters in London, the Secretary being the active officer. Accounts are kept of upwards of two thousand pairs af stations, and the clerical force in the office and inspectors at junctions numbers upwards of two thousand. Demurrage and lost baggage are departments of the Clearing House, but especially its function is the interchange of traffic, passenger and freight. There is also connected with the Clearing House, an Employee's Pension Fund, which it is hoped will become universal, so that the individual corporation funds may be absorbed by it. This is under the supervision of a sub-committee, and does its work effectively.* It would seem as if our American lines would soon recognize, as have already two of them, the importance of making their employees feel that in old age they will be cared for, to make the love and interest of the corporation take the place of the mutual insurance companies and organizations, many of which are inadequately administered. The employee is but a human being, and if one will appeal to him and impress him that the corporation is his best friend, his loyalty can be assured with us as it is in England.

While the Railway Clearing House, as I have said, has no dealings with the public, the *Board of Trade*, by its regulations and special committees established in 1840, covers the relation. Rate making has been the subject of special Parliamentary commissions from time to time. In addition to individual inquiries, the Board of Trade prescribes certain rules in regard to signals, safety appliances, reports on important accidents, inspection of new property before it can be operated, and like duties. The cost necessitated by English standards of construction have virtually been prohibitive of the construction of light branch lines in the agricultural district of the United Kingdom. There is a strong effort being made to relax these standards to enable the construction of new secondary lines of this class. Mr. Bryce, the late President of the Board of Trade, has given this matter much personal attention.

Operating expenses on the leading lines average less than 55 per cent., but their large capitalization only enables them to pay about 6 per cent., and often less. There would seem to be nothing new or

* "The Railway Clearing House" and other pamphlets published by the Clearing House.

novel engaging attention, simply the minor improvements suggested by experience. Electricity is not yet a factor. English practice is unquestionably well adapted to English conditions, but save in a few details, it would not meet American demands, nor would our practice successfully meet English conditions.

A few remarks may now be in order as to the International Congress. The Congress held its first meeting in 1884 to commemorate the fiftieth anniversary of the opening of Belgian railways. At the call of the Belgian Government, delegates from the Government and Railway Administrations of Europe assembled at that time at Brussels, to discuss matters of interest in the working of railways. The Congress does not deal with what we understand to be traffic, but with transportation ; nor does it prescribe standards or vote on questions except its own administration. Any railway in the world may become a member of the Congress through payment of a small annual due, receiving the *Congressional Bulletin*, which is of great value. It has met in Paris, Milan and St. Petersburg. Sessions are conducted in French, and in the language of the country in which it is held. This necessitated that the discussions in London be held jointly in French and English. The English-speaking representation is now so large that it is hoped that all publications heretofore only in French will be hereafter in French and English.

Wherever the Congress has met, it has received the hospitality, not only of the railways of the country, but of the Governments themselves. The Pennsylvania Railroad has, until of late, been the only American representative, but at the London session, some fifteen American companies had become members. The questions chiefly dealt with consist of those relating to permanent way, rolling stock, station service, signaling and general operation. In London the meetings were held at the Imperial Institute, a magnificent building near South Kensington Museum. The organization of the Congress consists of an Honorary President of the Session, which at the London session was His Royal Highness, the Prince of Wales ; a President, which was Lord Stalbridge. There is an international Permanent Commission or an Executive Committee made up of prominent men from all nations, having a permanent president, M. Du Bois, the Chief Administrator of the Belgian State Railways. The five sections into which the Congress is divided for purposes of discussion have a chairman at each session.

Questions are submitted by the Permanent Commission to various authorities, whose reports are printed and distributed prior to the assembling of the Congress. These are supposed to be thoroughly read by the delegates, and on them the discussion is held. Certain conclu-

sions are expressed but are in no sense binding, and merely indicate the outcome of varied experience and views. At the London session nearly a thousand delegates from all parts of the world assembled. The next session of the Congress is to be held in Paris in 1900, but many of the Commission are extremely anxious that an intermediate session should be held in America, as the Congress has heretofore held sessions at from two to three years intervals. It would seem very desirable to those interested in the science of railways in this country, that they should endeavor to secure such session, as it would, without doubt, serve to eradicate certain notions of American practice in European minds. Possibly, then, we could persuade the Europeans that a steel fire-box will not leak; that an automatic signal is reliable, and a chilled wheel safe.*

I shall close with a short itinerary of the social features of the gathering. A number of the Americans left New York on the "City of New York," on the 10th of June, having an enjoyable trip. On arriving at Southampton, through the courtesy of the London and Southwestern Railway, a special train was placed at their service, carrying them quickly to London. Having arrived some time prior to the opening of the Congress, the party devoted their time to special excursions and sight-seeing. Their headquarters were at the Victoria Hotel, where the American Railway Association had provided parlors and a secretary. The opening ceremony took place on June 26th, at the Imperial Institute, presided over by the Prince of Wales, who made a most interesting address, and, in the course of his remarks, said:

"I have to discharge to-day a very pleasing and very important duty in declaring open the Fifth Session of the International Railway Congress. I fulfill this duty on behalf of the Queen, who takes great interest in the discussion of matters so closely affecting the welfare of her Dominion. I do so on my own behalf, being glad of the opportunity of expressing my deep appreciation of the Railway Authorities, and I perform it, finally, in the name of the great railway companies of this country, which are governed by men of highest ability and skill, who have asked me to be their spokesman. I welcome to England, the birthplace of railways, the delegates from the Continental States, and representatives, I think the first time in the history of these Congresses, from the two Continents of America. The last Congress, which assembled in St. Petersburg in 1892, was made memorable by the splendid hospitality

* Since the paper was read the letter of M. DuBois to Mr. Ely, of the Pennsylvania Railroad, indicating that under the rules it will now be impossible to arrange a meeting in the United States prior to 1900, but expressing a desire that the next meeting thereafter be held here, has been made public in *Proceedings of the Western Railway Club.*

and great encouragement given by the late lamented Emperor of Russia. I fear, we cannot promise you the beauties of Italy or the gayety of Paris, but we can show you Manchester, Liverpool, Cardiff and Crewe, great centers of industry, from which I hope you will be able to derive some useful knowledge. I venture to say this, even to our friends from the United States."

This address was followed by Mr. Bryce, President of the Board of Trade, the author of the "American Commonwealth," by M. Du Bois, and by Lord Stalbridge, the President of the Session, and Chairman of the London and Northwestern.

That evening a reception was tendered at the Foreign Office by Mr. Bryce, at which the Prince of Wales, his suite and many of the prominent men of English public life were present. The members of the Congress were next offered the hospitalities of the various English railway companies to make excursions of three days before the business sessions opened the following Monday. Excursions to the Severn Tunnel and the Welsh Coal Fields were offered by the Great Western to the Midland Counties by the Midland Company, to Darlington and the East Coast by the Great Northern, and to Crewe and beyond by the London and Northwestern. The party of the London and Northwestern consisted of nearly 200, leaving Euston by special train on Thursday morning, making the run of 156 miles with but one short stop at Rugby. The train was hauled by the engine "Greater Britain," Mr. Webb's well-known compound exhibited at Chicago, and run by the engineer who prides himself on saying that he is the only man who has run a train from Euston to Chicago, for you will remember that this engine ran to and from Chicago under steam. Directly behind the engine was placed the dynograph car, which indicates the work of the engine, and was followed with considerable interest by many of the delegates. Mr. Webb himself accompanied the train. The pull on the draw-bar as we left Euston was nearly ten tons, the train being composed of saloon carriages and dining cars, part of the regular West Coast Joint Stock. On reaching Crewe the delegates were shown through the works which are the headquarters of the mechanical part of this great system. Here rails are made and locomotives and signal apparatus, but the carriage or coach department has a separate establishment at Wolverton, and the wagon or freight car department at Earlstown near Liverpool. The party passed through the shops, absorbing as much as possible of the many interesting features. Sample engines of all types were drawn up on the track for inspection, and among others the "Charles Dickens," the engine most famous in the world for having made the great mileage of upwards of a million miles in less than ten years. In daily service to-day she runs from Manchester to London and back, a mileage of 366½.

The London and Northwestern Railway is the most important example of a corporation buying nothing but raw material. Whether on the whole it has been beneficial not to assist the great manufacturers along the line, and thereby get assistance from them in the way of traffic, is questionable. At Crewe works seventy-five hundred people are in constant employment. A lunch was served in the draughting office works, after which, further inspection being made, the party proceeded to Liverpool for the night.

The writer in company with two other Americans, desiring to make the most of his time, preceded the party to Liverpool and inspected that evening the Edge Hill yards. The next morning we started for Harwich to see the newest and, in many respects, the best railway shop in England, that of Lancashire and Yorkshire. Through the kindness of Mr. Aspinall, Superintendent of Motive Power, we were enabled to examine these shops more in detail than we could have done by waiting for the party, which would arrive there in the afternoon. This wonderful big little road has a mileage of 487 owned and running powers over 170 additional, all in the manufacturing and mineral regions of the counties of Lancashire and Yorkshire. It owns 1,200 locomotives, has a capital of £47,000,000, gross earnings £11,000,000 and expenses £6,000,000.

Two of us then proceeded across England, stopping two hours to visit the Royal Agricultural Show at Darlington, thence on to Edinboro; the next day across the Forth Bridge, and spending the day in the Highlands, returned to London on Monday morning, somewhat used up after a rough night on an antiquated Pullman car on the Midland from Glasgow. The roughness of riding of some of the English tracks is remarkable. The cars do not seem to curve with the ease that they should, though this was not as noticeable in the Pullman car as it was afterwards in a so-called sleeping saloon of the London and Northwestern.

The active work of the session began on Monday morning and continued every day for ten days. The sessions were of interest. Some delay was caused by interpreting into the other language, as the speaker might speak in French or English. However, having read the bulletins we were enabled to follow the conclusions with interest, if not the discussions. On Tuesday evening the first banquet was given by the English Railway Association at the Imperial Institute, presided over by Lord Stalbridge. After the customary toast to "The Queen," Lord Stalbridge, in proposing "The Guests," expressed pleasure at meeting on that occasion representatives of nearly every railway in the world. "The moment was a proud one for England, seeing that this was the first time that the representatives of the great railways of

the Western Continent had been present in such numbers with them, and he hoped that at some future time it would be their lot to be invited to the United States."

On Wednesday afternoon short excursions were provided out of London. The most interesting one to the speaker being that of the Canterbury Cathedral, as the guests of the London, Chatham and Dover. There we were met by the Bishop of Dover and shown through the cathedral and grounds, being given tea in the historic library. Returning in the evening, we were still the guests of the London, Chatham and Dover, at a banquet given at the Free Masons' Tavern. At the close of this banquet, I expressed a desire with several of the Americans, to see an English freight station at night. We proceeded to the Broad Street Station and there remained some time.

Thursday evening we attended a banquet of the American Society in London, being the Fourth of July. On Saturday Her Majesty tendered a garden party at Windsor Castle. Special trains were placed at the disposal of the Congress by the Great Western and South Western, which conveyed upwards of a thousand people. On arrival the guests were conducted through the state apartments, St. George's Chapel, and the Albert Memorial Chapel, and the grounds of the castle. Her Majesty, accompanied by their Royal Highnesses, Prince of Wales and other members of the Royal Suite, drove through the grounds, bowing to the assembled party. Later a small party of representative men from various parts of the world were presented to Her Majesty. During the afternoon two regimental bands were playing and a delightful tea was served in the garden.

The writer, being somewhat anxious to return, was unable to join the parties which left after the close of the session for Scotland and Ireland. Leaving London on Sunday, I journeyed by the London & Northwestern to Stranrear, there taking the short Irish Channel passage to Belfast, spending one day at the Giant's Causeway. The next day I left Belfast in the early morning on the Great Northern at seven, having a most enjoyable breakfast in the dining car on that line, arriving in Dublin in the forenoon; after some hours in that city I took the afternoon train for Cork, enjoying the picturesque Irish country. Next morning I proceeded to Queenstown and there found the "Majestic," arriving in New York just five weeks to the hour from when I had departed, having travelled some two thousand miles on English railways.

QUADRUPLE EXPANSION ENGINES FOR LAKE SERVICE.

By Walter Miller, Member of the Civil Engineers' Club of Cleveland.

[Read before the Club, January 14, 1896.*]

In August, 1885, the writer had the privilege of presenting to this Club a paper on the subject of compound engines for lake service. In that paper, predictions were made regarding the probable advance in marine engineering on the lakes within the next five years, an advance which would result in an increase of the steam pressures considerably above that deemed sufficient at that time, and in an extension of the application of the well-known principle of expansion, which has been largely the cause of the phenomenal increase of the tonnage on the great lakes. To what extent these predictions have been verified, will be seen.

When that paper was written, the steam pressures were limited, owing to the difficulties encountered in building boilers to carry a pressure much greater than 100 pounds per square inch. In the low pressure engines that had formerly been used for service on the lakes, any attempt to increase the steam pressures resulted in increased condensation and re-evaporation; besides augmenting to a great extent other evils incident to the increased number of expansions attempted in the single cylinder engine. In the compound system that had been introduced, the steam was expanded in two cylinders instead of in one, thus largely reducing the losses caused by condensation and re-evaporation. Besides, the economy of the steam consumed per indicated horse-power, was so clearly demonstrated that its further advance was seen to be, beyond all question, in the direction of a higher steam pressure and a further development of the well-known system of compounding.

In November, 1887, a little over two years later, the writer again had the privilege of presenting to this Club a paper on the subject of triple expansion engines for lake service. In this second paper, it was shown that the steam pressures had been increased from 100 to 160 pounds per square inch, and that this increase of pressure had resulted in the abandonment of the old fire-box boiler, so long in use for lake service, and had led to the adoption of the large plain shell internally fired, or Scotch boilers. For riveting, bending and drilling the heavy plates required for these boilers, heavy machinery had to be introduced

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to an extent little dreamed of in the early days of the lake marine; and the steam, instead of being expanded in one or two cylinders, was expanded in three, still farther reducing the losses caused by condensation and re evaporation. It was predicted also in this paper that a still further increase of pressures might be looked for in the near future, and that a further development of the principle of expansion would result in a further reduction of the steam consumed per indicated horse-power.

The paper that the writer has the honor to present to the Civil Engineers' Club of Cleveland to-night, treats of Quadruple Expansion Engines for Lake Service, thus marks a step further in the development discussed in the two earlier papers. In the present paper, it will be shown that the steam pressures have been increased from 160 to 195 pounds per square inch, and that the steam is now expanded in four cylinders instead of one, two, or three. In the fall ot 1892, the Northern Steamship Company, operating the Great Northern System of Railways in the Northwest, decided to build two fast express steamers for exclusives passenger service on the great lakes. These steamers were to run between Buffalo and Duluth, stopping only at Cleveland and Detroit, and touching at Sault Sainte Marie while passing through the rivers, canals, and lock between Lake Huron and Lake Superior, on their way to Duluth, where they connect with the great Northern System of railroads, mentioned above. After mature deliberation, and a large amount of preliminary work, it was finally decided to build two vessels, having an average speed of twenty miles per hour, and equipped with quadruple expansion engines and water-tube boilers.

The following table gives the dimensions of the hull, and other particulars:

Length over all	383	feet.
Length between perpendiculars	360	"
Breadth, moulded	44	"
Depth, moulded	26	"
Load draught	14	"
Load displacement	4,482	tons.
Tonnage, gross registered	4,244	"
Tonnage, net	2,340	"
Capacity of coal bunkers	1,000	"
Capacity of water bottom	680	"
Tonnage, cabin	442	"
Tonnage, steerage	211	"
Tonnage, crew	143	"
Tonnage, total	800	"

Figs. 1, 2, 3 and 4 are upper, saloon and main deck plans and profile of the vessel respectively, and show the general arrangement of cabin, state and dining rooms, space for crew, machinery, etc.

The vessels are driven by twin vertical quadruple expansion engines, with the high pressure cylinders forward, and with dimensions, etc., as follows:

Diameter of high pressure cylinders	25	inches.
Diameter of first intermediate	36	"
Diameter of second intermediate	51½	"
Diameter of low pressure	74	"
Stroke	42	"
Total I. H. P. of the two engines*	7,000	pounds.
Steam pressure	195	"

Speed of vessel at 120 revolutions of the engine per minute,* 20 miles per hour.

Number of propellers (cast iron)	2
Number of blades in each	4
Diameter	13 feet.
Pitch	18 feet 6 inches.

BOILER (WATER TUBE) DIMENSIONS AND PARTICULARS.

Number in forward group	10	
Number in center group	8	
Number in after group	10	
Total	28	
Grate surface in one boiler	29	square feet.
Grate surface, total	812	"
Heating surface of one boiler	920	"
Heating surface, total	25,760	"
Ratio of heating surface to grate surface	31 to 1.	
Pressure allowed per square inch	267	pounds.
Total weight of engines and boilers	1,200	tons.

DESCRIPTION OF ENGINES.

Up to this time the use of quadruple expansion engines in this country was confined to yachts and other small steam crafts of high power and speed. The new American line steamships, "St. Louis" and "St. Paul," built by the William Cramp & Sons Ship and Engine Building Company, at Philadelphia, have quadruple expansion engines and Scotch boilers, but the steamers "Northwest" and "Northland" were the first vessels of great tonnage thus equipped. Their twin engines are of the vertical overhead cylinder quadruple expansion type, and were designed to develop 3,500 horse-power each, and to propel the vessel at an average speed of 20 miles per hour with 195 pounds of steam, the engines making 120 revolutions per minute.

The sizes of the cylinders as given above are 25 inches for the high,

* Estimated.

36 inches for the first, and 51½ inches for the second intermediate, and 74 inches for the low pressure, with a stroke of 42 inches. The high pressure cylinder is placed forward and is followed by the first and second intermediate and the low pressure cylinders. Piston valves are used throughout; one for the high pressure, and two each for the first and second intermediate and the low pressure cylinders. The valves are all arranged out-board on the working side, and all of them are operated by the Joy valve gear and reversed direct by steam and hydraulic gear. Where the valves are double, they are connected by a cross-head to which the radius rod of the valve gear is connected. The reverse arms are slotted and are fitted with blocks and adjusting screws. The engine columns, as shown in Fig. 5, are on the back or inboard side, and are of cast iron, forked, and of box section braced together with cast iron flanged distance pieces. The columns are fitted with detachable water-back guide faces. The columns of the front, or working side of the engine, are of wrought iron turned, to which are attached, by brackets, the reverse shaft and curved links for the valve gear. The cylinders are without liners or steam jackets, and the valve chests are connected by faced joints and by body-bound bolts. The low pressure and second intermediate cylinders are fitted with cone-shaped cast steel pistons, while the first intermediate and high pressure cylinders are fitted with cast iron pistons, all of which are completed with followers and single ring packing of cast iron, set out with flat bent springs. The piston rods are of steel, but do not extend through the top cylinder heads. The rods are secured to the pistons by quick taper and nut. The lower end is fitted with brasses, binder plate and bolts, forming the journal for the top end of the connecting rod. The cross-head, which is of the slipper pattern, is of cast iron and fitted with adjustable brasses, and is bolted to the piston rod. The connecting rod is of forged iron, with the lower end T-shaped, and is fitted with adjustable brasses lined with babbitt metal and secured to the rod by plates and bolts. In the middle of the connecting rod forged jaws are slotted out to receive the brasses to which are connected the vibrating levers of the valve gear. The upper end of the rod is forked and fitted with a steel pin that engages the cross head as already described. The bed plate is of cast iron and is made in four sections, planed and bolted together with body-bound bolts. The main journals in the bed plate are bored out and faced at the ends. Brass bushes, without flanges and lined with babbitt metal, are fitted into the bed plate, top and bottom alike, secured in place by cast iron liners, binders and bolts.

The thrust block is of the horse-shoe type, with cast iron adjustable shoes faced with babbitt metal. The shoes are adjustable, fore and-aft-wise, by thin nuts on two long screws, one on each side of the thrust

3

block. The sole plate of the thrust block is bolted to the bed plate on the after side. The total bearing of the main journals in the bed plate is 10 feet 8 inches. The intermediate bearings are lined with babbitt metal and placed at proper intervals to support the line shafts. Each crank shaft is built up in four duplicate parts. Each section is built up of two collared shafts, one crank pin and two crank slabs, all of forged iron, fitted and forced together by hydraulic pressure, and securely keyed. The length over all of each crank shaft for each engine is 22 feet 8 inches. The crank slabs are fiddle-shaped, 21 inch centers, 10$\frac{3}{8}$ inches thick, and 27$\frac{1}{2}$ inches diameter across the eye. The short sections of the collared shafts are 13$\frac{3}{4}$ inches diameter in the bearing, 25$\frac{1}{2}$ inches diameter at the couplings, and 14$\frac{1}{2}$ inches diameter where they fit the eye of the crank slabs. The line shafting for each set of engines consists of five pieces, one thrust shaft 13 feet 8$\frac{1}{2}$ inches long, 13$\frac{1}{2}$ inches in diameter in the body, and 13$\frac{3}{4}$ inches diameter in the bearing, and 20 inches diameter of thrust collars with flanges of same dimensions as those on the crank shaft. The first and second lengths of the line shaft are 20 feet $\frac{1}{4}$ inch long each, and the third section is 25 feet $\frac{1}{4}$ inch long, all 13$\frac{1}{2}$ inches in diameter in the body of the shaft and 13$\frac{3}{4}$ inches diameter at the bearings, with solid forged couplings of same dimensions as those on the crank shaft. The propellor shaft is 22 feet 1 inch long over all, 13$\frac{3}{4}$ inches to 13$\frac{7}{8}$ inches in diameter, and is covered with a brass sleeve 56 inches long at the bearing in the stern tube. This makes the total length of shafting, including the crank shaft, 123 feet 6 inches for each engine. The propellors are four bladed, sectional wheels of cast iron, made right and left, 13 feet diameter, with an expanding pitch of 18 feet 6 inches, and fitted to the shaft by taper, key and nut.

As previously stated, the valves are operated by the Joy valve gear, in which the valves obtain their movement from a combination of two motions, one being taken from the connecting rod at a point near the middle of its length and the other from a pair of curved links. This combination of levers for operating the valves is so proportioned, from the point of connection with the connecting rod, that the short end of the lever has a movement equal to that required for the laps and leads of the valves of the cylinders. The cross-head that forms the fulcrum for the short end of the lever, works in two curved links which are pivoted to the bearings on the front of the engine. These links are curved to a radius equal to the length of the valve rod. Thus it will be seen that when the curved links are at right angles to the valve rod, the valves have a motion equal to the laps and leads only, and that the required port opening is obtained by tipping or rolling the curved links up or down, as the case may require, corresponding to the go-ahead or backing position. The lower ends of the curved links are connected

to the blocks in the slotted reverse arms by two short eye bars. Hence the point of cut-off can be regulated to any desired extent by the adjusting screw in the reverse arms. The main reason for adopting the Joy valve gear in this case was to reduce the fore-and-aft length of the engines, as this arrangement renders it unnecessary to provide room for eccentrics or space between cylinders for valve chests. Besides, the lead remains constant at all points of cut-off.

The engines are fitted complete with relief valves at each end of each cylinder and in the receiver chests. Drain valves are fitted to the bottoms of the cylinders and value chests.

The air pumps and condensers are detached and are worked independent of the main engines. They are of the jet condensing vertical compound direct connected type, with a high pressure cylinder 15 inches and a low pressure cylinder of 30 inches bore, and a stroke of 18 inches. The air pumps are single-acting, 38 inches bore by 18 inches stroke. The piston rods of the steam cylinders are continuous into the air pump, and the high and low pressure cylinders are connected together by double beams linked to cross-heads keyed to the piston rods. The condenser is bolted on the side of the channel plate, and is fitted with cone, spray nozzles, injection valves, etc. The feed pumps are located in the engine room and are quadruple, with double-acting steam cylinders and single-acting water plungers. All are connected by cranks and fly wheels. The cold water bilge, ballast and sanitary pumps are of the duplex type and are all located in the engine room.

To sum up, there are twenty-one pumps with twenty-eight steam cylinders and twenty-two water cylinders, six centrifugal pumps and nine other engines with sixteen steam cylinders and six blowers. If we include three electric plants, with their three engines and air pumps, and the main engines with their eight steam cylinders, there are in all sixty-five steam cylinders and twenty-six pump cylinders on board the "Northwest."

It is in the steam generating plant that there is the greatest departure from existing methods, and time alone will determine whether these will prove suitable for general use in the merchant marine. The boilers were invented by M. Belleville, of the firm of Delauney, Belleville & Co., of St. Denis, Seine, France, and were introduced in this country by their agent, Mr. Miers Coryell, of New York. There are in the steamer "Northwest" twenty-eight Belleville patent water tube boilers, which are divided into three groups. They were designed to generate steam sufficient for the main engines to indicate 7,000 horse-power and for auxiliary machinery 500 horse-power motor with natural draught. Fig. 6 shows the front and side of one generator, and Fig. 7 shows one of the boiler rooms, with a group of four boilers. The boilers are joined together

back to back in-board, directly over the keel line of the hull. They occupy the center of the vessel, one-half of each group facing out-board and then come the fire rooms, one on the port side and the other on the starboard side. Outside of the fire rooms, and extending to the sides of the vessel, are the coal bunkers. The boilers are entirely below the main deck. The groups are so arranged that there are ten boilers in the forward fire room, eight in the middle and ten in the after one. Each group has its own smoke funnel, and each has two fire rooms connected by a cross passage. The boilers are 12 feet 9 inches and the fire rooms 6 feet 7½ inches, athwartships from face to face. The outer limits of the fire room are the fore-and-aft bunker bulkheads, which are 26 feet apart; and, as the extreme beam of the vessel is 44 feet, there is left for bunker space 9 feet at the widest part. The bunkers will store about a thousand tons of coal. The three groups of generators, the cross passages and the fire rooms occupy a floor space 26 feet wide by 124 feet long. The extreme height of the boilers is 11 feet.

As before mentioned, the total grate surface in each boiler is 29 square feet, and the total for the twenty-eight boilers is 812 square feet of grate, while the heating surface in one boiler is 920 square feet, and the total heating surface in the twenty-eight boilers is 25,760 square feet. The ratio of heating to grate surfaces is 31 to 1, the maximum pressure allowed is 267 pounds per square inch, and the total weight of the boilers, with water, is 400 tons. The grates are of the Ætna shaking pattern.

As will be seen from the illustrations, each boiler consists of a series or set of tubes or elements placed side by side over the fire and enclosed in non-conducting casings. Each element is in the form of a flattened spiral, and consists of straight tubes connected at the ends by junction caps of malleable cast iron. The caps are placed vertically one above the other, and the upper end of one tube is on the same level as the lower end of the one above it. Holes, provided with doors, cross bars and bolts, are fitted in the front caps for inspection and cleaning. The tubes are slightly inclined to the horizontal, and the lower caps of each element are connected at the front of the boiler with a horizontal cross tube called the feed-collector tube. The upper tube is connected to the lower part of a cylindrical steam receiver placed outside of the boiler casing. A vertical circulating pipe, also placed outside the casing, conveys the down current to a mud drum placed at the base of the boiler, the upper part of which is connected to the feed collector. The feed water is delivered into the steam receiver at the ends remote from the inlet of the downcast pipe. Thence it runs along the receiver bottom, down the external pipe, through the mud drum and into the feed collector, and thence into the several elements to be heated by the

action of the fire, on its upward way through the tubes, from which it emerges into the receiver a mixture of water and steam. Here the steam is separated, by suitable baffle and dash plates, from the water, which, with the addition of the fresh feed water, again passes along the receiver bottom to the downcast pipe, and follows the same course as before. The feed water is supplied by the feed pump, and its admission to the receiver is regulated by a self-acting gear of novel design. The water stand-pipe is connected to the top and bottom caps of the outside elements, and in it is pivoted a float which rises and falls with the level of the water in the stand-pipe, opening and closing, by means of suitable gear, a balanced feed-check valve of special design fitted on to the receiver. The water-level in the stand-pipe is maintained at a constant height, which, when the boiler is under pressure, with the tubes full of a mixture of steam and water, is on a level with the fourth tube from the top. The forced circulation of water is caused by the difference in density between the water in the downcast pipe and the mixture of the steam and water in the element tubes. On leaving the receiver, the steam is led through a separator formed with a self-acting trap.

One of the main features of the Belleville system is that the boiler pressure should be considerably in excess of the working pressure of that required for the engines, to which it is reduced by means of a suitable reducing valve. The reason for M. Belleville's preference for very high pressures is that, besides increasing the economy of evaporation, it facilitates the separation of the earthy salts contained in the feed water. The solubility of these salts decreases as the temperature of the water increases, and here we have the reason for introducing the feed water at the ends of the reservoir remote from the downcast pipes, and leading it through the entire length of the receiver. The salts, which are principally sulphates and carbonates of lime, are precipitated, and fall to the bottom of the sediment chambers or mud drums, whence they are blown off as often as required. The time required for raising steam is, of course, extremely short.

This is a description of the motive power of the steamers "Northwest" and "Northland," and, while many of the members of this Club saw the second set of machinery nearly finished in the erecting shops of the builders, and a few had the opportunity of seeing the engines in motion on some of the initial trips, yet to those that have not had these opportunities some further description is necessary to a full understanding of the principles involved. The steam is admitted to the high pressure or forward cylinder, and is cut off at about $\frac{4}{10}$ of the stroke, expansion taking place during the remainder of the stroke. The steam is then exhausted into the receiver space between the first and second cylinders, and from this space it is admitted to the first intermediate

cylinder and is cut off in the same manner as in the high pressure cylinder. It continues through the second intermediate cylinder to the low pressure cylinder, whence it is exhausted into the condenser. It will be seen that with a $\frac{4}{10}$ cut-off in the high pressure cylinders, and a cylinder ratio of 8.07 from the high to the low pressure, the number of expansions would be over twenty. The steam is not admitted to the high pressure cylinders at the full boiler pressure, but is reduced from about 225 to 195 pounds per square inch by means of a reducing valve under the control of the engineers. As has already been explained, the steam, as fast as it is generated, passes up through the flattened spirals of the several elements on its way to the steam receiver, carrying with it large quantities of water from which it has to be separated. This is accomplished by baffle plates and screens arranged in the steam drum or receiver, and the process of separation is further assisted by the steam in the boiler being kept at a greater pressure than that delivered to the engine ; in other words, by reducing as much as possible the velocity of the steam in the main steam pipe, on its way to the engines, by means of the large reducing valves already referred to.

The sequence of the cranks are : low leading, followed by the second and first intermediate and high pressure. The reduction of the extreme weights between the high and low pressure pistons is greatly assisted by making the low pressure and second intermediate pistons of cast steel, and the first intermediate and high pressure pistons of cast iron, while the high pressure piston is solid, and the first intermediate piston nearly so. With the sequence of cranks as described, the low pressure and first intermediate pistons are diametrically opposite and of nearly the same weight, while the second intermediate and high pressure pistons are opposite and of nearly the same weight, making a very evenly balanced engine. It can thus be turned up to a high rotative speed in order to obtain the piston velocity required, and this is accomplished with but little vibration. With such high steam pressure great care and good judgment must be used in arranging the piping and valves. All the joints are flanged and made male and female. Otherwise the high steam pressures can be used with very little difficulty

The most interesting part of this subject is yet to be touched upon, viz., what economy has been effected by the increased steam pressures carried and by these improved methods of working the steam expansively. Owing to the wide difference in the systems to be tested, and in the conditions under which the tests must be made, it is not possible to estimate the economy with any degree of accuracy by tests, except in a general way. In making such an estimate, we must consider to what extent, if any, and to what parts, steam jacketing had been applied, or whether the receivers were or were not furnished with re-heaters, their size and

location, the sequence of cranks, whether the engines are for land or marine service, under what conditions the tests were made, the design of the steam generators used, whether these are externally or internally fired, water-tube or otherwise, their evaporative equivalent and many other conditions, besides making due allowances for inaccuracies in the instruments or errors on the part of assistants. These are usually unknown quantities until after the test is made and the results are figured up, and they are then made large or small or according to the interest of the parties making the guarantee. Thus it will be seen that while tests are made to determine the relative efficiency of engines and boilers for the lake service, and while they are as accurate as circumstances will permit, and of value in determining to what extent improvements on any system in use are, or can be made, their results can show only in a general way what is being accomplished. Tests made in each individual case cannot be accepted as conclusive, nor will the summations prove beyond all question that the results may not be different under different conditions. The figures given below show the average economies of the different systems, based on the result of numerous observations and actual tests made, and are not to be taken as representing the best that has been done in either of the systems.

System.	Steam Pressure.	Steam consumed per indicated horse-power.
Low pressure	60 pounds per square inch	36 pounds
Compound	100 " " " "	16 "
Triple expansion	160 " " " "	12 "
Quadruple expansion . . .	195 " " " "	11 "

In other words, the economy of the compound system over the low pressure is 55 per cent.; that of triple expansion over the compound is 24 per cent.; and that of quadruple over triple expansion is 10 per cent.

The writer is indebted to the editors of the *Marine Review* for the use of the plates from which the illustrations are printed.

DISCUSSION.

MR. JOSEPH R. OLDHAM.—I rise with pleasure to congratulate Mr. Miller on his excellent work connected with the boilers and machinery of the "Northwest." When we consider the exigencies of the trade in which that steamer and her sister, the "Northland" have engaged, it will at once be evident that the designing and construction of such vessels on these lakes was a great achievement. Although the design of the boilers was not Mr. Miller's, he had the responsibility of

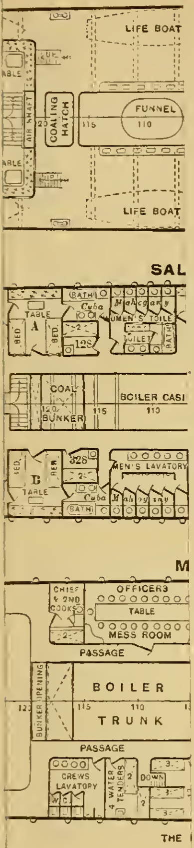
their arrangement in the steamer, and, though the design is French, the workmanship is purely American, for I believe that every pound weight of those boilers was made in Cleveland, O. The problem facing the designer of the "Northwest" was a most difficult one, for throughout a great part of the voyage the most suitable steamer would be a side-wheeler, such as the "City of Detroit," whilst a small Atlantic liner would not be too large nor too staunch for the Fall trade in Lake Superior. The "Northwest" did her season's work without losing a trip, and this achievement redounds with unalloyed credit to the designers and builders.

As Mr. Miller's paper is on quadruple expansion, it may be well for us to consider the object in view in adopting multiple expansion. The economy resulting from the adoption of triple or quadruple expansion lies in limiting and lessening the range of temperature. For instance, look at the old one-step condensing engine. The range of temperature was generally over one hundred degrees, and when pressures went up, the heat did not rise in anything like an equal ratio. Consequently, by dividing the expansion into three or four steps, we reduce the range of temperature in each cylinder by about one-half; but it should be borne in mind that the principle of expansion is the same, whether steam be expanded in one or in any number of cylinders.

The energy exerted by a fluid depends on the change in temperature and in volume which it undergoes and not on the number and arrangement of the cylinders. For instance, the bulk of the steam in the "Northwest's" high-pressure cylinder at the instant of cut-off would exert the same amount of energy if passed directly into the low-pressure engine as it does after passing through all the cylinders, although this is of course modified by the cylinder condensation and re-evaporation.

Let me say a word about the Scotch boiler, and I have done. I would not like to see such a safe, reliable and useful old friend depart, if go it must, without a hearty farewell; and, with a view to its retention as long as possible, I think this Club might press upon our Inspectors the necessity for relaxing their rules with regard to the cylindrical shell. I never knew of a marine boiler shell exploding, and when I add that the shells of our boilers are about 50 per cent. heavier than the British Admiralty require for immense fleets, you will surely agree with me that we might reduce the thickness of our boiler shells with advantage and without running any undue risk.

Mr. Richard L. Newman.—I congratulate the author of the paper just read, and I congratulate the city of Cleveland on the possession of such an able engineer. Mr. Oldham has just remarked that he thinks the Scotch boiler will remain with us for a number of years yet, but I must differ from him on this point, as I believe we shall, in a very short time,


LIFE BOAT
COALING HATCH
AIR SHAFT
FUNNEL
110
115
LIFE BOAT
SAL
BATH
Cuba
TABLE
A
BED
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WOMEN'S TOILET
TOILET
BATH
128
COAL
BUNKER
BOILER CASI
328
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MEN'S LAVATORY
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CHIEF & 2ND COOKS
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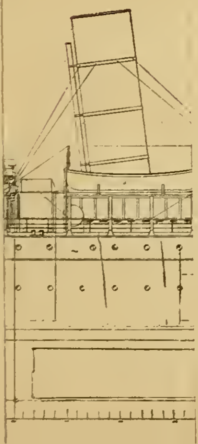


UPPER DECK PLAN

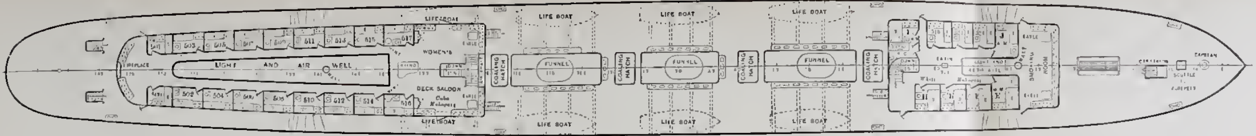


Fig. 1.

SALOON DECK PLAN

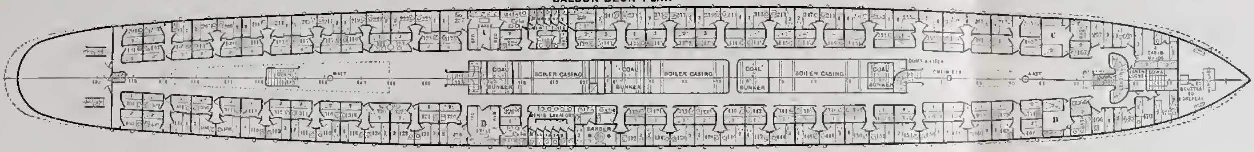
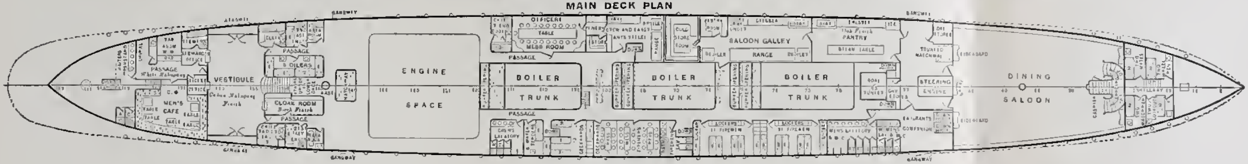


Fig. 2.

MAIN DECK PLAN



THE M-H CO., BUFFALO, N. Y. 8468 E

Fig. 3.

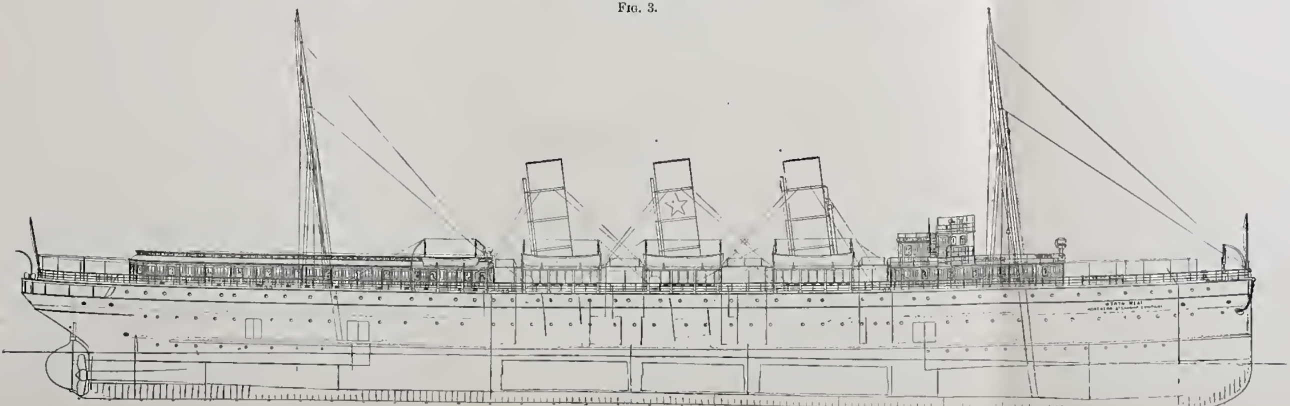


Fig. 4.

PLATE I.

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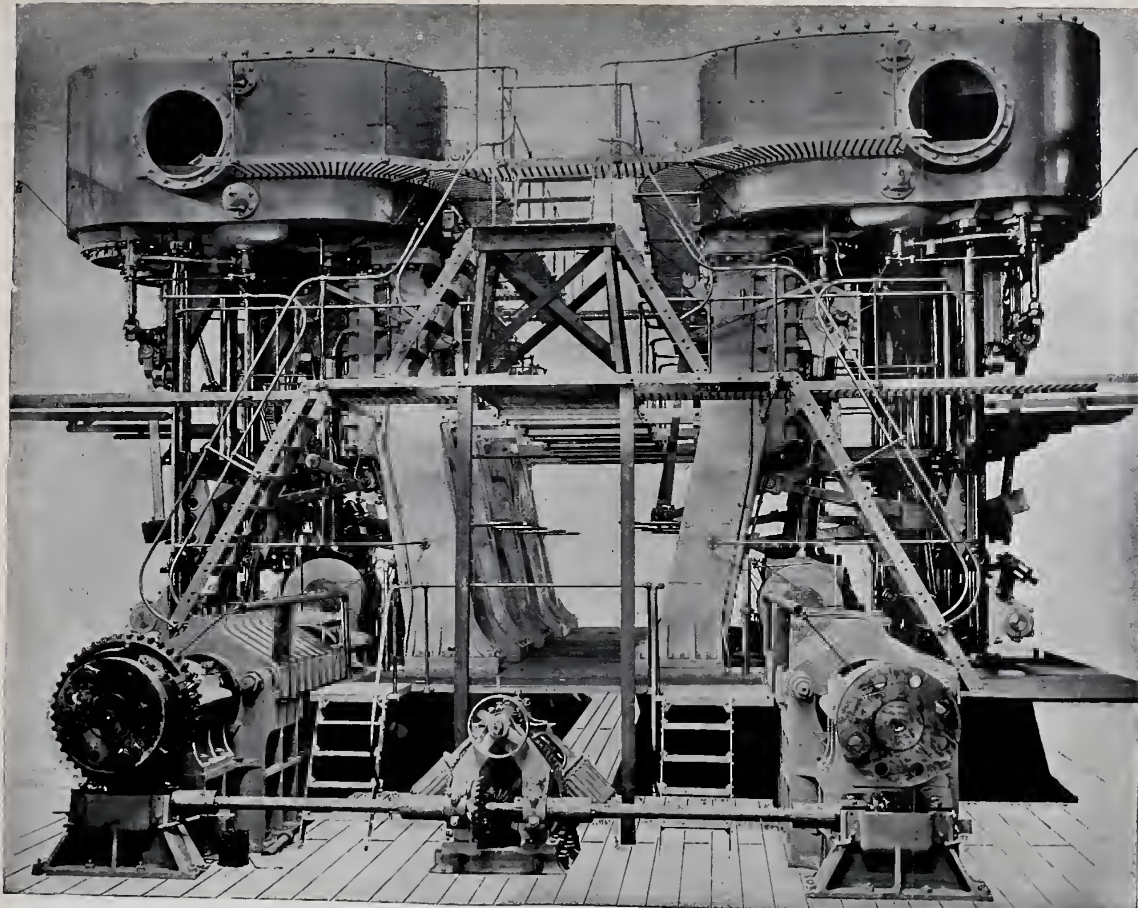


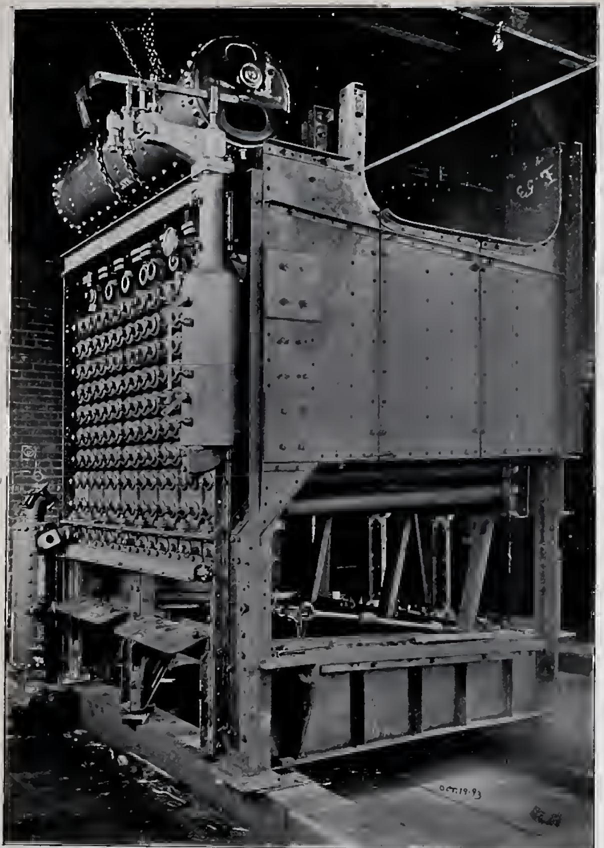
FIG. 5.—QUADRUPLE EXPANSION ENGINES, STEAMSHIP "NORTHWEST."

7,000 indicated horse-power. Cylinders 25, 36, 51½ and 74 by 42 inches. Steam furnished by twenty-eight Belleville boilers.

PLATE II.

E WA

at total 81



IN PROCESS OF CONSTRUCTION, SHOWING FIRE SPACE AND TUBE ENDS.

FIG. 6.

IN ONE OF THE BOILER ROOMS, SHOWING A GROUP OF FOUR BOILERS.

FIG. 7.

BELLEVILLE WATER TUBE STEAM GENERATORS.

Number 28. Space occupied, 8 by 8 feet. Grate surface, 29 square feet, total 812 square feet. Heating surface, 22,736 square feet. Total weight, complete with water, 812,000 pounds.

PLATE III.

see very rapid progress in the adoption of the water-tube boiler. Mr. Miller in his remarks referred to the "St. Louis" and the "St. Paul," and in this connection I think we might, with advantage, make a few comparisons. The weight of machinery, as given by Mr. Miller for the "Northwest," was 1,200 tons for 7,000 indicated horse-power. The former gives us 5.9 indicated horse-power per ton of weight. That of the latter ships is 6.66 indicated horse-power per ton of weight. This, to me, is rather a surprise, as I would naturally look to the application of the water-tube boiler as resulting in a saving of weight, in addition to its ability to carry a higher steam pressure; but here we have Scotch boilers showing quite as good results, if not better, than those of the Belleville boiler.

Quite recently I was engaged on several schemes in connection with the proposed battleships Nos. 5 and 6. Here we proposed to fit a Niclausse water-tube boiler and expected a saving, in regard to weight carried, of about 40 per cent. Our estimates on the Yarrow boiler promised quite as liberal results In support of this I quote the French cruiser "Friant." This boat was fitted with a battery of twenty Niclausse boilers, and developed, on trial, an aggregate horse-power of 9,500. The weight of these boilers was, with water and all fittings, about 260 tons. The estimated weight of a battery of Scotch boilers, for the same power, would be about 500 tons, which, as you see, is greatly in excess of the weight of the water-tube boiler.

One gentleman desired to know the effect of the application of the reducing valve between the boiler and the engine. In 1886, I was engaged on the designs of a torpedo gunboat for the Russian government. This boat was fitted with a battery of Belleville boilers. I think the general impression then was that the reducing valve tended to dry the steam, that is to say, that, owing to the fact that the steam expanded without doing external work, the extra heat was absorbed by the steam and tended to superheat it.

I agree, also, with Mr. Oldham in his remarks as to the strength of the boiler shell being in excess of that actually required; for a number of years I have been engaged in both the designing and construction of boilers, where we allowed a factor of safety of not more than four. One of these boiler shells was subjected to water pressure, and was found to be practically indestructible, so far as the testing machinery then at hand was concerned. This, then, seems to show that a factor of four is quite sufficient for a boiler. In answer to your respected Secretary, I would say that there is not the slightest doubt in my mind that the machinery of the "St. Louis" and "St. Paul" is the finest on any trans-Atlantic liners now running.

I thank you for the courtesy extended to a stranger, in permitting him to join in this most interesting discussion.

ASSOCIATION OF ENGINEERING SOCIETIES.

Articles of Association.

The following Articles of Association were adopted at a meeting held in Chicago, December 4, 1880. At this meeting there were present representatives of the

Western Society of Engineers,
Civil Engineers' Club of Cleveland,
Engineers' Club of St. Louis;

and the

Boston Society of Civil Engineers

was represented by letter.

FOR THE PURPOSE OF SECURING THE BENEFITS OF CLOSER UNION AND THE ADVANCEMENT OF MUTUAL INTERESTS, THE ENGINEERING SOCIETIES AND CLUBS HEREUNTO SUBSCRIBING, HAVE AGREED TO THE FOLLOWING

ARTICLES OF ASSOCIATION.

ARTICLE I.

NAME AND OBJECT.

The name of this Association shall be "THE ASSOCIATION OF ENGINEERING SOCIETIES." Its primary object shall be to secure a joint publication of the papers and transactions of the participating societies.

ARTICLE II.

ORGANIZATION.

SECTION 1. The affairs of the Association shall be conducted by a Board of Managers under such rules and by-laws as they may determine, subject to the specific conditions of these articles. The Board shall consist of one representative from each society of one hundred members or less, with one additional representative for each additional one hundred members, or fraction thereof over fifty. The members of the Board shall be appointed as each society shall decide, and shall hold office until their successors are chosen.

SEC. 2. The officers of the Board shall be a chairman and secretary, the latter of whom may or may not be himself a member of the Board.

ARTICLE III.

DUTIES OF OFFICERS.

SECTION 1. The Chairman, in addition to his ordinary duties, shall countersign all bills and vouchers before payment and present an annual report of the

transactions of the Board; which report, together with a synopsis of the other general transactions of the Board of interest to members, shall be published in the Journal of the Association.

Sec. 2. The Secretary shall be the active business agent of the Board and shall be appointed and removed at its pleasure. He shall receive a compensation for his services to be fixed from time to time by a two-thirds vote. He shall receive and take care of all manuscript copy and prepare it for the press, and attend to the forwarding of proof-sheets and the proper printing and mailing of the publications. He shall have power, with the approval of any one member of the Board, to return manuscript to the author for correction if in bad condition, illegible, or otherwise conspicuously deficient or unfit for publication. He shall certify to the correctness of all bills before transmitting them to the chairman for countersignature. He shall receive all fees and moneys paid to the Association and hold the same under such rules as the Board shall prescribe.

ARTICLE IV.

PUBLICATIONS.

Section 1. Each society shall decide for itself what papers and transactions of its own it desires to have published and shall forward the same to the Secretary.

Sec. 2. Each society shall notify the Secretary of the minimum number of copies of the joint publications which it desires to receive, and shall furnish a mailing-list for the same from time to time. Copies ordered by any society may be used as it shall see fit. Payments by each society shall in general be in proportion to the number of copies ordered, subject to such modification of the same as the Board of Managers may decide, by a two-thirds vote, to be more equitable. Assessments shall be quarterly in advance, or otherwise, as directed by the Board.

Sec. 3. The publications of the Association shall be open to public subscription and sale, and advertisements of an appropriate character shall be received, under regulations to be fixed by the Board.

Sec. 4. The Board shall have authority to print with the joint publications such abstracts and translations from scientific and professional journals and society transactions, as may be deemed of general interest and value.

ARTICLE V.

CONDITIONS OF PARTICIPATION.

Section 1. Any society of Engineers may become a member of this Association by a majority vote of the Board of Managers, upon payment to the Secretary of an entrance fee of fifty cents for each active member, and certifying that these Articles of Association have been duly accepted by it. Other technical organizations may be admitted by a two-thirds vote of the Board, and payment and subscription as above.

Sec. 2. Any society may withdraw from this Association at the end of any fiscal year by giving three months' notice of such intention, and shall then be entitled to its fair proportion of any surplus in the treasury, or be responsible for its fair proportion of any deficit.

Sec. 3. Any society may, at the pleasure of the Board, be excluded from this Association, for non-payment of dues after thirty days' notice from the Secretary that such payment is due.

ARTICLE VI.

AMENDMENTS.

These articles may be amended by a majority vote of the Board of Managers, and subsequent approval by two-thirds of the participating societies.

ARTICLE VII.

TIME OF GOING INTO EFFECT.

These articles shall go into effect whenever they shall have been ratified by three societies, and members of the Board of Managers appointed. The Board shall then proceed to organize, and the entrance fee of fifty cents per member shall then become payable.

These articles were adopted by the several societies upon the following dates:

Engineers' Club of St. Louis, January 5, 1881.
Civil Engineers' Club of Cleveland, January 8, 1881.
Boston Society of Civil Engineers, January 19, 1881.
Western Society of Engineers, April 5, 1881.

The Board of Managers was organized at Cleveland, January 11, 1881.

The following societies have since certified their acceptance of the Articles, and have become members of the Association of Engineering Societies:

Engineers' Club of Minneapolis, July, 1884.
Civil Engineers' Society of St. Paul, December, 1884.
Engineers' Club of Kansas City, January, 1887.
Montana Society of Civil Engineers, April, 1888.
Wisconsin Polytechnic Society, June, 1892.
Denver Society of Civil Engineers, January 24, 1895.
Association of Engineers of Virginia, February 1, 1895.
Technical Society of the Pacific Coast, March 1, 1895.

The Wisconsin Polytechnic Society withdrew from the Association in March, 1894.

The Western Society of Engineers withdrew in December, 1895.

Annual Report of the Chairman of the Board of Managers.

St. Louis, December 31, 1895.

To the Members of the Board of Managers of the Association of Engineering Societies.

Gentlemen:—In submitting to you herewith the report of the Secretary of the Association, I desire to call your attention to the apparent excess of our assets over our liabilaties for the year of $223.73. The recent withdrawal of the Western Society of Engineers, from the Association, would seem to entitle them to their portion of this excess, but inasmuch as $316.55 of these assets consist of subscriptions overdue, and of accounts for sales and advertisements, on which some considerable loss must be anticipated, it is evident that no final settlement with the Western So-

ciety for a credit to them of any portion of this apparent excess can be made at this time.

So far as I know there is now perfect harmony between the various societies belonging to the Association, and an entire satisfaction on their part with the management of the affairs of the Association by the Board. The Chairman wishes again to publicly acknowledge the valuable service of our efficient Secretary and to solicit in his behalf the cordial assistance not only of the members of the Board, but of the officers and members of the several societies in the Association. His services to the Association cannot be measured by the meager salary which we can afford for this work.

The Chairman bespeaks, also, for the editor of the *Engineering Magazine*, such assistance on the part of the Board, and of the officers of the several societies, as will enable him to successfully supply the members of these societies with copies of the bound volume of Index Notes which have appeared in our JOURNAL for the past four years, and which he will supply to the members of the societies in the Association at the price of $2.50 each, whereas the price to all other parties will be $4.00. The Chairman has assured him that no undue advantage will be taken of this reduced rate to our own members, and furthermore that the officers of the several societies would assist him in carrying out this business arrangement. It is hoped also that those of our readers who have valued our Index Department will subscribe for the *Engineering Magazine*, in which this department will be maintained on a much more elaborate scale, and so remunerate the editor of that Journal for the great additional expense involved in its adoption of our style of index.

The Chairman wishes also to thank the members of the Board and the officers of the various societies in the Association, for their courteous and considerate acquiescence in such executive decisions as he has been called upon to make. In the absence of meetings of the members of the Board, it is often impractical to submit questions to the entire Board for decision, and many things have thus to be determined by the Chairman and Secretary on their own responsibility. During the past two years a much larger amount of business has come before the Board than in any similar period before, and yet no meeting of the Board has been held. The Chairman bespeaks, therefore, for Mr. S. E. Tinkham, of Boston, the Chairman elect, the same spirit of helpful compliance which they have shown to their retiring Chairman.

Respectfully submitted,

J. B. JOHNSON, *Chairman.*

Annual Report of the Secretary of the Board of Managers.

PHILADELPHIA, DECEMBER 31, 1895.

Prof. J. B. Johnson, Chairman.

WASHINGTON UNIVERSITY, ST. LOUIS, MO.

DEAR SIR:—I have the honor to present the following report upon the operations of the Secretary's office during the year 1895, and of the condition of the Association at the present time.

The following is a statement of the receipts and expenditures during 1895:

CASH, 1895.

Dr.

To Balance, January 1, 1895	$330 44		
" Initiation Fees:			
Denver Society of Civil Engineers	13 50		
Association of Engineers of Virginia	17 50		
Technical Society of Pacific Coast	80 00		
		$111 00	
" Assessments:			
Boston Society of Civil Engineers	1,043 56		
Western Society of Engineers	1,475 25		
Civil Engineers' Club of Cleveland	663 78		
Engineers' Club of St. Louis	629 11		
Civil Engineers' Society of St. Paul	119 37		
Engineers' Club of Minneapolis	123 25		
Engineers' Club of Kansas City	100 00		
Montana Society of Civil Engineers	165 72		
Denver Society of Civil Engineers	88 85		
Association of Engineers of Virginia	102 75		
Technical Society of the Pacific Coast	292 75		
		4,804 39	
" Subscriptions		594 14	
" Sales of JOURNALS		247 36	
" " Descriptive Index, 1884–91		40 00	
" Advertisements		679 84	
" Sales of Reprints		264 25	
" Interest on Deposits		3 63	
" Postage refunded		3 72	
			$7,078 77

Cr.

By Edward Stern & Co., Incorporated (Printers)	$4,700 00	
" Illustrations	716 39	
" Secretary's salary	600 00	
" Linotype composition	197 00	
" Index compilation, 1894	175 00	
" Traveling expenses	145 66	
" Car fares	4 96	
" Typewriting, etc.	20 75	
" Mimeographing	38 90	
" Advertising	8 32	
" Discounts on subscriptions	18 41	
" " sales	3 75	
" Commissions on advertisements	80 75	
" Allowance to Western Society of Engineers, account T. L. Condron	1 50	
" Messenger service	13 64	
" Stationery	13 15	
" Telegrams	8 42	
" Postage stamps	42 07	
" Affidavit	1 00	
" JOURNALS bought	3 50	
" " returned	30	
" Directing envelopes	6 00	
" Express and freight charges	10 57	
		$6,810 04
" Cash Balance December 31, 1895		$268 73

Estimate of Assets and Liabilities at the Close of 1895.

AVAILABLE ASSETS.

Cash balance December 31, 1895		$268 73	
Less subscriptions for 1896 paid during 1895		34 25	
			$234 48
Amounts receivable from Societies (for assessments, etc.):			
Boston Society of Civil Engineers	308 10		
Western Society of Engineers	47 25		
Civil Engineers' Club of Cleveland	4 00		
Engineers' Club of Minneapolis	77 28		
Engineers' Club of Kansas City	134 01		
Montana Society of Civil Engineers	48 00		
Association of Engineers of Virginia	6 75		
Technical Society of the Pacific Coast	122 50		
		747 89	
Subscriptions due:			
For 1895	41 50		
" 1894	24 00		
" 1893 and earlier	12 00		
		77 50	
For Reprints		158 30	
" Advertisements		97 00	
" Sales of Journals		12 25	
" Sales of Index, 1884–91		12 00	
" Linotype metal		58 40	
			$1,163 34
			$1,397 82

LIABILITIES.

Edward Stern & Co., Incorporated (Printers):			
Ledger balance	$200 85		
For December Journal	539 34		
" Reprints, 1895	70 00		
		$810 19	
Bradley & Poates:			
Wax process, engravings		82 00	
Burk & McFetridge:			
Photolithography		69 00	
Philadelphia Inquirer Co.:			
Linotype Composition		15 43	
Philadelphia Typewriter Exchange		8 52	
J. B. Johnson, Index Compilation, 1895		175 00	
Engineers' Club of St. Louis		9 75	
Civil Engineers' Club of Cleveland		4 00	
			$1,173 89
Excess of Assets over Liabilities			$223 93

The deficit of $758.91, existing at the close of 1894, was covered by an extra assessment of 66 cents per member.

Cost of JOURNAL During 1895.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	Composition.	Paper, Presswork, Binding.	Wrapping, etc.	Postage.	E. Stern & Co. Sum of 1, 2, 3 and 4.	Illustrations.*	Index Compilation.	Cost of Manufact'e Sum of 1, 2, 6 and 7.	Wrappers.	Secy's Salary.	Sundries.†	Total.	No.‡ of Pages.	Cost per Page.
January	$188 53	$231 00	$6 50	$14 64	$440 67	$105 75	$14 58	$539 86	$5 36	$50 00	$42 09	$658 45	162	$4 06
February	120 89	168 60	6 19	12 33	308 01	39 50	14 58	343 57	5 37	50 00	42 09	459 55	118	3 89
March	160 49	239 60	6 74	18 97	425 80	44 00	14 59	458 68	5 37	50 00	42 09	581 85	190	3 06
April	88 03	176 65	5 50	12 50	282 68	93 75	14 58	373 01	5 37	50 00	42 09	488 47	106	4 61
May	114 64	158 45	3 00	13 87	289 96	30 00	14 58	317 67	5 37	50 00	42 09	432 00	130	3 32
June	156 12	224 75	6 54	17 31	404 72	177 89	14 59	573 35	5 37	50 00	42 09	694 66	148	4 69
July	74 99	119 75	6 45	11 05	212 24	36 23	14 58	245 55	5 36	50 00	42 09	360 50	92	3 92
August	89 42	143 35	6 45	11 89	251 11	68 89	14 58	316 24	5 37	50 00	42 09	432 04	88	4 91
September	59 91	97 40	6 43	7 08	170 82	14 25	14 59	186 15	5 37	50 00	42 09	297 12	64	4 64
October	63 32	114 40	6 35	6 72	190 79	28 73	14 58	221 03	5 37	50 00	42 09	331 56	76	4 36
November	61 85	114 40	6 35	8 63	191 23	30 00	14 58	220 83	5 37	50 00	42 09	333 27	74	4 50
December	191 37	316 30	6 35	25 32	539 34	190 61	14 59	712 87	5 37	50 00	42 10	842 01	234	3 60
Totals and averages	$1,369 56	$2,104 65	$72 85	$160 31	$3,707 37	$859 60	$175 00	$4,508 81	$64 42	$600 00	$505 09	$5,911 48	1482	$3 99

* The figures in Column 6 include preparation of cuts and lithographic stones, and paper and presswork on insets.

† The figures in Column 11 include Secretary's trips to Chicago, etc., $94.45, and to Pittsburg, $31.21, and all other expenditures of the Association (such as stationery, postage, circulars, etc.), chargeable to the JOURNAL, and not embraced in any of the other columns. They do not include the cost of preparing reprints of papers.

‡ The figures in Column 13 include 4 cover pages in each number, and 24 pages in indexes to Vols. XIV and XV.

The cost of the Index to Engineering Literature, for 1895, was approximately as follows:

Compilation		$175 00	
Composition:			
Linotype	$115 63		
Making up	87 61		
		203 24	
Rearranging for December	$22 50		
		225 74	
List of periodicals indexed:			
Charge for type standing, 4 pages, say		7 00	
Paper, presswork and binding:			
11 months, 145 pages, say 9 forms, at	$21 75		
		195 75	
December, 110 pages, 7 forms, at	$21 75		
		152 25	$755 74

The use of the linotype machine has thus effected a reduction of about $170 in the annual cost of this department; but, by order of the Board of Managers, the publication of this index in the JOURNAL ceased with the December number of 1895.

By direction of the Board of Managers "the Contribution Box" and "the Library" were discontinued also.

The mailing lists of the JOURNAL, at the close of 1894 and 1895, compared as follows:

	1894.	1895.
Boston Society of Civil Engineers	353	390
Western Society of Engineers	337	401
Civil Engineers' Club of Cleveland	187	139
Engineers' Club of St. Louis	163	170
Civil Engineers' Society of St. Paul	34	32
Engineers' Club of Minneapolis	33	25
Engineers' Club of Kansas City	25	22
Montana Society of Civil Engineers	42	64
Technical Society of the Pacific Coast		168
Denver Society of Civil Engineers		28
Association of Engineers of Virginia		38
	1174	1477
Extra copies to members of the Board of Managers, five each	70	80
Advertisers	27	23
Exchanges	110	122
Subscribers	176	215
Complimentary copies	15	18
	1572	1935

Besides this, many copies have been sold and specimen copies sent out; and authors of papers have each received five copies of the JOURNALS containing them. Of the January number 2,200 copies were printed, and 2,400 of each of the others.

Vol. XIII (1894) contained 1,290 pages of printed matter, 86 cuts and 54 plates and full-page cuts.

The continued increase in the bulk of the JOURNAL rendered it advisable to divide the twelve numbers issued during each year into two volumes. Those for 1895 comprise Vols. XIV and XV, and contain, together, 1,482 pages of printed matter, 116 cuts and 66 plates and full-page cuts as follows:

	Papers.	Contribution Box.	Library.	Chairman's Report.	Pr'c'd-ings.	Index & Ads.	Total.	No. of cuts.	Plates & full-page cuts.
January . .	87	3	6	16	16	30	158	12	8
February . .	51	4	5		24	30	114	4	2
March . . .	133	4	3		25	21	186	19	2
April . . .	58	4	2		8	30	102	7	8
May . . .	82	0	2		10	32	126	0	1
June . . .	89		1		10	28	128	12	14
July	56				6	26	88	9	3
August . .	56				2	26	84	23	6
September .	28				4	28	60	6	1
October . .	32				10	30	72	13	0
November .	34				8	28	70	3	3
December .	86				12	126	224	8	18
	792	15	19	16	135	435	1412	116	66
Covers							48		
Index to Vol. XIV . . .			16						
" " " XV . . .			6				22		
Total							1482		

The number of pages issued in 1895 thus exceeds, by 192, or about 15 per cent., that of 1894 (Vol. XIII), which was the largest that had appeared up to that time; and the JOURNAL for December, 1895, with its 230 pages, is the largest that has been issued by the Association.

The following table exhibits a comparison, in several particulars, between the operations and condition of the years 1894 and 1895:

	1894.	1895.
Excess of liabilities over assets, December 31	$758 91	
" " assets over liabilities " "		$223 93
Number of Societies in Association " "	8	11
Number of names on mailing lists of Societies in Association " "	1,174	1,477
Number of subscribers " "	176	215
Annual receipts from subscribers, @ $3.00	$528 00	645 00
Number of advertisers	25	23
Annual receipts from advertisers	$850 00	679 84
Total pages in JOURNAL	1,290	1,482
" cost of "	$5,774 59	5,911 48
Cost per page	$4 48	3 99
Average number of copies issued monthly	1,958	2,383
Number of small cuts	86	116
" " plates and full-page cuts	54	66
Cost of illustrations	$651 60	859 60
" " index to current literature, approximate	$926 00	755 74

The JOURNAL has throughout the year enjoyed the advantage of second-class or "pound rates" of postage (1 cent per pound).

Of the 50 copies of the bound volume of the "Descriptive Index," covering the years 1884–1891, accepted from Mr. John W. Weston, the former Secretary of the Association, in settlement of a balance amounting to $72.02, sixteen copies have been sold, realizing $37.50.

During the year, the Technical Society of the Pacific Coast, numbering 168 members, has become a member of the Association. The union between the ten societies now forming the Association is thus made co-extensive, in longitude, with that between the States of the Union, reaching from the Atlantic to the Pacific.

In March I visited Cleveland, Indianapolis, Louisville, Cincinnati, and Pittsburg, on behalf of the Association.

At Cleveland I attended, by invitation, the banquet of the Civil Engineers' Club of that city, one of the four original societies forming the Association, and received many hearty assurances of the loyalty of the Club to the organization.

In Chicago I attended, with you, also by invitation, a meeting of officers and prominent members of the Western Society of Engineers, held for the purpose of considering those matters which had led certain members of that society to desire its secession from the Association.

As you will remember, we were assured by those present at the meeting, that all the matters in dispute had been satisfactorily adjusted, and that the question of secession was thereby rendered a dead issue.

On the 24th of September last, the Society, by letter ballot, reversed its action of 1894, and decided, by a vote of 179 to 87, to withdraw from the Association.

In Indianapolis, Louisville, Cincinnati and Pittsburg, I met with members of the societies in those cities and laid before them the advantages of membership in the Association.

In April, I again visited Pittsburg and addressed the Society there upon the same subject.

Very respectfully yours,

JOHN C. TRAUTWINE, JR.,

Secretary.

Editors reprinting articles from this journal are requested to credit both the JOURNAL and the Society before which such articles were read.

MAR 17 1896
PATENT OFFICE

ASSOCIATION OF ENGINEERING SOCIETIES.

Organized 1881.

VOL. XVI. FEBRUARY, 1896. NO. 2.

This Association is not responsible for the subject-matter contributed by any Society or for the statements or opinions of members of the Societies.

ENGINEERS—CONSULTING, INSPECTING, CONTRACTING.

Their Relationship to each other and to their Clients.

By GEO. W. DICKIE, MEMBER OF THE TECHNICAL SOCIETY OF THE PACIFIC COAST.

[Read before the Society, June 2, 1895.*]

IN opening up the questions that naturally gather around the title of this topical subject, I do not expect to be able even in the most limited sense to do so exhaustively with regard to any one of the divisions under which I desire to arrange my remarks.

My object in presenting this subject now, is to bring out, if possible, a general expression from the members of this Society, of how these questions have affected them in their practice.

We have members whose special line of work comes under some one of the divisions I have made, and who must have very decided opinions in regard to the duties and obligations of engineers whose work would be classed under some other division than that in which they themselves are placed.

I am fully alive to the danger incurred in treating this subject and I shall be careful to avoid any expression that might tend to wound any of those whose friendship I hold in the highest esteem. So, if I do say anything that hurts, let it be understood that the reference is not to the practice of any local engineer, but to some bad practices I have read about as being done in the East and in Europe.

* Manuscript received January 15, 1896.—*Secretary, Ass'n of Eng. Socs.*

Naturally, and by preference, due to my limited knowledge, my remarks will have special reference to mechanical engineering. Other members, skilled in the practices of the civil branch of our profession, will, I trust, take up these questions, and tell us how things are done in the various relationships in which civil engineers stand to each other and to their clients.

As I will confine my remarks to what I have observed in connection with my own experience, my task will be an easier one than if I had to look up the statements of others and find authority for accepting them myself or for presenting them to you as truth.

I have placed the consulting engineer in the first division of this subject, because I think the position he occupies, or should occupy, is of the first importance. Great interests, affecting not only his clients, but, it may be, the welfare of a whole community, often depend upon his judgment.

In the mechanical branch of the profession there are not many consulting engineers that meet my idea of the requirements of that position. Standing, as he does, as a judge between the individual or the corporation who provides the means to carry out an enterprise, and the other individual or corporation, who, for the money expended, is to produce the plant required for the purposes of such enterprises, he must, in order to be successful, possess complete and accurate knowledge not only of the things required, but also of the capacity and ability of the men that are to produce these things.

A consulting engineer, if he has the full confidence of his client, gives advice, not only as to the materials which his client needs for the purpose he has in view, but also as to whom he should employ to produce these things. This is the most difficult duty required of the consulting engineer, and the one that gives him most trouble; for, amongst all the contracting engineers that are desirous of having his client for a customer, only one will approve of his advice; all the others will accuse him of ignorance, and some of them, may be, of something else. It is, therefore, of the first importance that the consulting engineer should possess a most complete and accurate knowledge of the latest and best practice in regard to all the matters on which he is consulted.

Some engineers are honest and will not pretend to give advice unless they are conscious of their ability to give their client the very best thing possible for the purpose in view. Others are simply after the consulting fee, and run around amongst the manufacturing engineers, getting this one's idea and that one's idea, and out of these patching up a sort of specification that the client accepts as his engineer's requirements for the work on hand, while, if he had gone direct to any one of the sources where his engineer got his information, he would have got a specification that at least one man could give a fair bid on.

This kind of consulting engineer has of late fallen into a trick of protecting himself by specifying that the work he is supposed to have planned out and carefully described, is to perform certain functions under certain conditions, and with a certain minimum economy, and the hapless contractor is required to guarantee that the result will be at least equal to that specified.

If the consulting engineer is competent to do what he has undertaken, he will also have confidence enough in his own work to be able to assure his employer that the result expected will be obtained without placing a third party in a false position.

In other words, why should the engineer's client ask a contractor to insure him against any mistake he may have made in employing the wrong man as a consulting engineer?

It appears to me that, as things are now, there is a grand opportunity for an Engineering Insurance Company which would employ the best talent in each line of work, and to which capitalists would submit plans and specifications prepared by their consulting engineer; and, should the Insurance Company's experts approve the plans, they would be accepted as a reasonable risk and the result insured in a sum equal to the cost thereof, at a reasonable premium.

This practice on the part of consulting engineers, of requiring a contractor to guarantee that their design will accomplish all that they have promised their client, has become so much a matter of course that we are never surprised even at the most childish expression of it in a specification.

Looking over a contract and specifications for barges, drawn up by the consulting engineer for a Russian company, the other day, I found the following:

After giving plans and dimensions for the barges and specifying the weight of material, the engineer requires the contractor to guarantee that the said barges will carry 500 tons on 3 feet 6 inches of fresh water.

Now, to his employers, this engineer appears to be protecting their interests, but if he had specified something to be 10 feet long, and then required the contractor to guarantee that it would be 120 inches long, they would have thought him rather too childish for a consulting engineer.

There are, however, some notable exceptions to this type of consulting engineer. Some two weeks ago I had to estimate the cost of large pumping works designed by Mr. E. D. Leavitt, of Cambridgeport, Mass. The drawings were very complete in every detail, clearly figured out and so indexed for reference that the work of estimating was a pleasure. The specification was brief, and stated distinctly the point

of beginning and the point of ending of the proposed work, and what was meant by the words used in the drawings. The contractor was held responsible for the quality of material used and of work done thereon. But he was not asked to guarantee that Mr. Leavitt's design of engine would successfully accomplish the results that he had promised. In fact, the economic result expected of this design was a matter that lay entirely between the water board of the city and their consulting engineer, and with which the contractor had nothing to do. In this respect Mr. Leavitt sets a good example to the consulting engineers of the country, and his reputation is largely due to the fact that nothing leaves his office until it is thoroughly worked out, and no outsider is asked to take the responsibility of any design bearing the name of E. D. Leavitt.

This is the position I would like to see all consulting engineers take in regard to their work. It would add to the dignity of the profession. The client would be more careful as to whom he employed as engineer advisor. The contractors would not be tempted into promising impossibilities, and in the end resorting to trickery to hoodwink an incompetent engineer into believing that the impossible had been realized, at least in this one case.

If my friend, the consulting engineer, will pardon my boldness, I will say to him, be sure of your ability and experience to plan the very best thing to fulfill the conditions of the problem you are to solve. Then go ahead, but don't ask a contractor to guarantee that you have not made a mistake.

The inspecting engineer may be either the consulting engineer himself, or his representative, or he may be an independent engineer employed directly by the principal party to the contract.

His duties are the same in either case, and consist in seeing that all the obligations under which the contract and specification places the contractor are faithfully fulfilled.

The inspecting engineer should have an accurate knowledge of all the detail of the work he is to inspect; should know the conditions under which each part of the work operates when performing the functions for which it was designed; besides, he should have a good knowledge of men and of their weaknesses, and above all he should have a good temper and a tender heart, for while he is expected to do justice, he should also love mercy.

Much of the trouble that often occurs between inspecting engineers and contractors is caused by improperly written specifications.

I sometimes think that specifications are written for the express purpose of preventing the contractor from building the work specified without evading the provisions of the specifications or coaxing the inspector to read them through his spectacles.

Why should a specification say that the material used should be the very best possible of its kind, when, of any two pieces of material taken at random, one will be better than the other, which would mean, by the language of the specification, that one shall be taken and the other shall be left. Why should castings be specified to be free from all defects, shrinkages, scales or scabs, when such a thing is the exception and not the rule. Why specify workmanship to be perfect, when there is no such thing as perfect workmanship.

I am in the habit of writing specifications in the following way: The materials used shall be reasonably good, and fit for the purpose for which they are to be used. Castings are to be good and sound, and reasonably free from defects that would affect their strength or sightliness. The workmanship is to be good, and of the character required for each part of the work. This is usually scratched out as not likely to produce the best result, and the usual absolute perfection is inserted, and coupled with another requirement, that the whole work must be done to the entire satisfaction of the inspecting engineer. This word, satisfaction, is a mistake, for an engineer may not be, and very often is not satisfied with work, when done according to the specifications and contract.

I once had to do work under an inspecting engineer, who claimed, that the clause, requiring that the work must be done to his entire satisfaction, meant that the work should be done over and over again until he was entirely satisfied; and when I required him to state what would satisfy him, he claimed that the specifications did not require him to instruct us what to do, but simply to say whether he was satisfied with it when done. He claimed, in effect, that, whatever his whim, caprice or notion required in order to be satisfied, we must meet the demand, for we had contracted to do this work to his satisfaction.

My idea of an inspecting engineer is, that he should be a consulting engineer to the contractor. It is unfortunate when inspectors are suspicious of the contractor, and the contractor is afraid to show to the inspector any little defect that he discovers. There should be mutual trust and confidence between them. A contractor should never ask an inspector to look at anything that he himself, if inspector, would condemn; but, if he has any work on hand wherein there has been developed some slight imperfection in material, or where some workman has made a mistake, so that the finished work will not be strictly according to the specifications, but quite good enough for the purpose for which it is to be used, he should be able to show it all to the inspector, confident that no advantage will be taken of his honesty. How often a contractor is driven, through fear of losing good property, owing to lack of confidence, to run the risk of an inspector failing to find out the defect in material, or

error in workmanship. Inspectors expect this course to be taken, and are slow to admit the possibility of an honest contractor. I have often asked inspectors to come and look at work that was not just as it ought to be, and yet altogether too good to condemn, and found that the fact of my pointing out the defect was enough to condemn the work.

One inspector used to tell me that he could not conceive of my calling his attention to work that I thought was good enough, and that my coming to him was, to his mind, an evidence that I did not want the work to pass, but that I wanted his assistance to condemn it. My experience is, that to call an inspector's attention to a fault, however slight, is to have the work condemned.

This is not the result of want of knowledge on the part of inspecting engineers, but is due rather to a misunderstanding between the parties in interest as to their relationship to each other. There should be full confidence between contractors and inspectors. Any defect, however slight, should be accepted, if at all, with the full knowledge of the inspector. The inspector should take into account all the difficulties that beset the contractor. Some inspectors appear to think that they are expected to earn their remuneration by making the work more costly to the contractor.

An old engine builder, on the water front here, said that he made a contract to build a set of machinery for a heavy tow-boat, and "I was dead sure," said he, "at the beginning, to clear $5,000 on the job, but they hired a man to prevent me from making that $5,000, and he was a splendid success; for, before the job was finished, the sheriff had my shop, and even he could not satisfy the inspector." Inspectors are not all of this type, however, and the better fitted they are for the responsible position they hold, the more pleasant the relationship will be between them and the contractor.

During the past six years or so I have had much to do with Government inspectors, and I had often been told how hard it was to get along with them; that nothing would satisfy their critical methods of inspection; and yet I have found the Government inspector not only a gentleman in the highest and best sense of the term, but also a great help in meeting the requirements of the contract. I have always felt perfecty safe in giving them full information in regard to all material and work, and have always found them ready to take a reasonable and practical view of the case. I am happy to be able to give this testimony and am proud of the professional staff that have represented the Government from time to time at our works.

In regard to the contracting engineer, I cannot speak so freely as I have done of the others. I belong to that class myself, and it is very difficult to see ourselves as others see us. Yet we are conscious of great

room for improvement in our methods of doing work, as well as in our relationship to the other two classes of engineers and to our patrons. Keen business competition makes the battle a hard one for the honest contracting engineer. Sometimes it would appear that the old road that leads to success, that of honesty and skill, combined with great pride in the character of the work turned out by his establishment, is no longer open to the contracting engineer. He must now aim at the greatest apparent result for the least cost. Each one tries to promise something more than his competitor, and the one that tells the best story, rather than the one who has the best skill, is apt to be entrusted with the work for which they are competing.

Change now seems to be written on every product of engineering skill. Work involving much thought and experience in its production is discarded for something else before it has had time to earn a reputation for the engineer that produced it.

In our time, business reputation depends not so much on what we have done as on what we propose to do next. Yet I am not ready to accept this condition as either permanent or true. And I would say to my brother engineers that I am more and more convinced that there is no near cut to engineering reputation, however much the rapid changes now going on in engineering practice may tend to deceive us into such belief. To reach a permanent reputation for great skill in any one line of engineering, our life must go into it, trudging along the old well-beaten track of honest, steady and intelligent effort. The value of what we produce should be measured, not by what we got out of it in the shape of profit or present notoriety, but by what we put into it of honest skill and ripe experience.

In the efforts now being made to draw trade to our State, let us avoid the miserable scramble after the cheap and temporary, for no lasting prosperity or individual reputation can be sustained on such a foundation. Let our aim be to produce the very best within the compass of our skill and then produce that thing, but no other, as cheap as possible.

Between consulting and contracting engineers there is not that desire for mutual helpfulness that there ought to be. The contractor is often ambitious to be the consulting engineer, and, in some cases where his experience gives him special fitness for this position, it is quite right that he should be so, and no antagonism should result from such practice. In certain branches of engineering, the contractor must maintain a large staff of skilled engineers at his works, and he is thus in a position to bring to bear on the problems an accumulation of skill and experience that no consulting engineer could match; but a contractor should be in such a position before he undertakes to come in between the consulting engineer and his client.

The position of the consulting engineer in California will, I think, improve. Capital is being more and more invested through corporations, and the consulting engineer must find his proper place as the technical advisor of such corporations.

We need a better understanding between the various branches of our profession. We must have a high standard set up for engineers to reach before being considered competent to give advice in regard to great engineering enterprises, or to inspect the work in progress. Nor should that standard be lower for the contracting engineer, who guides the skill which produces the results promised by the consulting engineer and satisfies the keen eye of the inspecting engineer who represents the interests of those who provide the needful.

DISCUSSION.

Mr. Richards.—Mr. Dickie has found no reason to impute dishonesty to a single individual, but attaches the highest integrity to the profession. Our romancers, in their novels, make villains of everybody but the engineer. There is no other profession that stands upon so high a plane morally and ethically.

Mr. von Geldern.—I beg to call Mr. Richard's attention to Charles Dickens' Pecksniff who may be counted among our fraternity.

Mr. Randell Hunt.—Mr. Dickie raises the question whether the Consulting Engineer should not maintain a position different from that which he now occupies, and whether corporations and others seeking the advice of engineers should not ask the advice of a Consulting Engineer where they now depend upon an engineer in their own employ.

I think there will be no advancement of engineering as a profession until the engineer ceases to be the contractor; until he occupies an entirely separate and distinct position. At present the drift is in the other direction. The engineer is becoming the contractor.

There have been issued recently, in this city, two sets of specifications for structural work. In one of them the specifications call for plans for the structure. In other words, the specialist's advice is sought. The engineer who drew up the plans is evidently not a specialist. I maintain that the proper position for a chief engineer is: To go out into the field of engineers and to employ a specialist to draw up the specifications for the structure he wishes to build. Instead of that he follows the usual rule, and specifies very broadly that he requires the structure to fulfill certain conditions, and wishes plans, etc., submitted. He is seeking, in other words, the advice of a dozen specialists for nothing, and he is going to get it, and perhaps more.

Looking at it entirely from his standpoint and the interest of the

corporation in which he is employed, he is probably doing his duty. But is he not lowering the status of the engineering profession? Is he not putting the engineer into the place of the contractor?

I am at present a contracting engineer. I am one of the unfortunates who are making plans on this proposition. I am giving a great deal of time merely for a chance to build this or that structure. I do not complain of the opportunity. I am seeking it in every direction in these hard times. But is it a proper and legitimate position in which to place the profession? I think not.

The other set of specifications is almost identical. It is seeking technical advice *for nothing*. The public has to pay in the end for all the plans that are made.

I maintain that engineers, if they are going to make a profession of engineering, must put themselves on a different basis. I see no reason why corporations should seek plans and original designs for nothing by thus asking for bids in competition, any more than a person should do so in building a house. The architect, in the building of a house, occupies identically the same position as the engineer occupies, or ought to occupy in his work. The architect is entirely independent of the contractor in every way.

Now, there is another way of looking at this. By going to a single specialist and having him draw up plans and designs, would the profession advance as much as it has done under the present system? Is it not a fact that the financial part of the proposition—the fact that the contractor becomes the engineer—is one of the chief incentives to an original design? Is not that the reason, or is it not one of the chief reasons why engineering, in almost all lines, has jumped forward with such bounds? The capitalist, for instance, says to his engineer: "That will not do; it is entirely too expensive." Such a remark will immediately make the engineer seek to construct on cheaper lines, and in that way he will develop a proper theory, one which can be applied at the minimum expense. That has been particularly the case in regard to civilengineering structures in this country.

I believe there is no country that has made greater advancements or has shown greater originality in structural work, than America, and the chief incentive to a correct design has been the financial problem.

Looking at it from this point of view you may say that the position I first took is entirely wrong. But I do not see it so. I think the engineer has a duty to himself to perform, and that duty will be best performed when he occupies a purely professional position.

There are certain points in Mr. Dickie's paper that strike me as though he were writing rather from the point of view of the contractor with reference to engineers, and from his experience with them in that

way. I have occupied the position of engineer, and that of contractor, and sometimes the dual position of both contractor and engineer; but I have found no dishonesty among engineers in the usual interpretation of the term. I have, however, found something of a disposition to saddle upon others the ignorance of the engineer. Mr. Dickie has, to a certain extent, brought out this point in his paper, by remarking that an engineer, after specifying various things, also requires that the work, or the structure, shall be perfect. That is always, in my opinion, a confession on the part of the man who draws up the specifications, that he is not quite sure of himself; that he does not know whether he has met the proposition quite as it should have been met. I regard this as one of the principal faults engineers should strive to correct. If an engineer is called upon to draw up a set of specifications not in the direct line of his specialty, let him do what he should do—frankly say that he wishes to call in special advice in the matter. There is hardly an engineer today, employed by a large corporation, who dares to do it. The employer will say, "What do I hire you for? If you do not understand the problem we will hire someone else." No man can acquire all the technical knowledge in the world. It is an advantage to have specialists, and we engineers understand that, perhaps, better than others. When an engineer is called upon to design something a little out of his line, he should frankly call in advice upon the subject, instead of obtaining it, as usual now, from others for nothing.

Prof. Marx.—What Mr. Hunt has said suggests to me that a little might be said on the other side.

It seems to me, for instance, that the calling for plans from several large contractors carries with it a certain advantage which will inure to the benefit of the corporation in whose employ the engineer may happen to be. The engineer should see in what way their interests are best served. It seems to me the middle way might be best for all.

Mr. Hunt suggests that an engineer may not be capable of drawing up all the plans for a particular piece of work. In this case a specialist might be called in to aid him in the outlines, but not necessarily in every detail. When bids are made from the plans submitted by the contractor, it is very often possible that practical modifications of the design, which will fulfill the object of construction, may be of great economic value, and the importance of such modifications cannot properly be overlooked by the engineer. Or it may be that the particular firm that has bid for the contract is in position, owing to certain local conditions, to use up a certain amount of material which it has on hand, if allowed to make certain changes, and those changes might not affect materially the use and durability of the structure.

I think, perhaps, a combination of the two methods might bring

about a more satisfactory result than is attained by holding the bidding firm strictly to the plan of the head engineer. Suppose he had drawn up certain plans. Is it desirable to bid on those plans alone? Would it not be wiser, and just as fair, to allow the bidders to make certain changes in the plans, if by so doing the structure could be as well built, and at the same time be a more economical structure for the corporation?

Mr. Hunt.—Does not this make it simply a matter of competition between engineers?

Prof. Marx.—Well, we will leave the decision to the consulting engineer, who has been employed by the chief engineer; he not being able to draw up the plans of the building, or to change the plans submitted.

Mr. Hunt.—I do not think there should be competition among professional men. I do not see any more reason for seeking competition among professional engineers in the matter of a design, in the ordinary course of work, than for seeking a competitive legal opinion on a matter; it would be identically the same proposition. If we are going to make a profession of engineering we must put a man upon a professional elevation, and seek his opinion, just as we would seek a medical or a legal opinion. We may not in this way get the best advice, any more than we can always be sure to get a correct interpretation of a mooted law point from one attorney. We would be very apt to get a better one if we made it a matter of competition among eight or ten attorneys, Undoubtedly a man is serving the interests of his corporation if he can. get the most for the least, but I do not view it in that manner.

Prof. Marx.—I did not take quite that extreme view. The plans are submitted to the approval of the consulting engineer. I think that in the large bridge structures on the Danube it was left to the bidding firms to submit bids on their own designs, and then the designs were submitted to the decision of a commission.

Mr. Hunt.—Undoubtedly that is an incentive to the production of numerous beautiful and original designs.

A Member.—Hawkesbury bridge was the result of the competition of the world. It was built for about one half what it would have cost without this competition.

What experience I have had has been with contracting firms in structural work. In submitting bids, the company I have been connected with prefers to prepare its own plans, at its own expense, rather than submit a bid on the plans of a consulting engineer. In bridge work especially, railroad companies prefer their own plans, as their workmen are familiar with their methods and details, and they can do their work much cheaper than if they were working under a new set of details.

It seems to me that the middle course would be the proper one in such cases, and that the consulting engineer could give a decision as to form and general dimensions, leaving it to the contracting firm to submit the details to be approved by the head engineer.

Mr. Hunt.—I have been talking directly against my own stand as a contractor. What I have said to-night is by no means my business opinion. It is an opinion that I am giving freely and frankly as an engineer. I am a contracting bridge engineer, and the gentleman has expressed my position in the matter plainly, and I do exactly what he says. It is for this simple reason that I prefer to submit my own designs, and I feel that I have a better chance in competition by doing so. But I must say that I do not think it a fair position to either party. In the first place, I do not believe in making a consulting engineer occupy the position that has been spoken of here. I believe consulting engineers should occupy purely the professional position of giving advice, making plans and specifications, and being paid for them. If a corporation wishes a special structure it should secure special professional advice.

Mr. Richards.—The position of the consulting engineer is a matter of evolution. It will be a quarter of a century before the consulting engineer in the United States will be in the position of the consulting engineer in Europe. His method and treatment will prove what I say. In one case the consulting engineer submits his views, and he is not supposed to know whether they are adopted or shown to anybody else. That is none of his business. That is the true consulting engineer, in the sense in which the term is used in the old country. In other cases his opinion is submitted to the principals of the works; and he appears before them, argues the points and shows wherein his method is correct.

The objection, on the part of employers, to calling in consulting engineers, exists in some cases, but not in all. A short time ago I was called upon to give advice in a very important case. It involved a matter of three million dollars. I spoke to the Commissioners about calling in additional advice and they said, "Certainly, call in some one else, or more than one, if you think best."

There are all kinds of conditions to be met. One cannot define just what the duties should be.

The first consulting engineer in the United States was Mr. Arthur, of New York. He opened his office about 1870. He was an old Scotchman. He was soon followed by Charles Copeland, who died a few months ago.

On this coast the idea is new. It has been forced upon the people. No one wants the consulting engineer, but he has to be employed.

Contractors, in most cases, I am happy to say, submit plans honestly and fairly. They do not always do so, nor do they always estimate on

a fair basis. Sometimes they form collusions—I have heard of such things; and the consulting engineer must be called in.

As I said before, it is a work of evolution. The position of the consulting engineer is entirely different from that of the civil or mechanical engineer. In static engineering one can get at the material, make computations, and devise plans very nearly alike. In machinery it is different. There is no standard at all for these things, they are not computable. The consulting engineer, in many of his operations, proceeds without any aid from books or personal experience. He must be about fifty years of age before he knows very much, and he then discovers that his knowledge, in many important details, is limited.

Mr. Byron Jackson.—I have had to do the consulting engineer's work from the standpoint of the contractor; that is, I have acted as both.

I think that the consulting engineer, as well as the contractor, should be made to compete.

In my opinion contractors should be made responsible for putting in the best material. I have to use that particular clause in my line of work, and I have found it necessary to say, "the best of its kind." It is a very simple matter to get over, and generally answers the purpose. We can spin the specifications out at length; but we are generally compelled to cut them short by saying that the material shall be of such a character. Of course, specifications should be explicit.

I believe that contractors, as a rule, can be depended upon as well as consulting engineers. They are compelled to act in good faith, for, if they do not, they will get no more contracts. Our people are perfectly willing to employ a consulting engineer, if such employment is not too expensive. I think that in many instances specialists should be called in to give assistance.

Mr. Bestor.—Mr. Hunt urged that the engineer, like the architect, should occupy a more independent position. There is just the same trouble with architects as with engineers and contractors. They are taking work for which they alone design the plans; except in the larger and better works, where they have the privilege of bringing in experts. Take electric lighting, for instance—where the expert is called in and is paid for his services. I do not see why the superintending engineer or the consulting engineer should not do the same thing.

It seems to me this question is open to much argument, and can be much varied. The standing of the consulting engineer will be defined by an evolutionary process, as Mr. Richards says. It will take time to improve it.

Mr. Dickie.—I do not know that I am under obligations to refer

to anything that has been said about this paper, because I simply undertook to open the discussion. I am not responsible for its outcome.

The main point that I wanted to bring out in the paper is that the consulting engineer should be sure of his own position, and when he specifies certain things, he should hold himself responsible for the result. The principal difficulty in the relationship between contracting and consulting engineers lies in this responsibility. It is not the fault, perhaps, of the consulting engineer, but that of his client. The party who is going to invest a large amount of money in some engineering enterprise, wants a guarantee that by the use of a certain amount of capital his project will prove all that his engineer proposes it shall. There is where the trouble lies. Those who invest should not ask a third party to guarantee their own design. If they employ a consulting engineer they ought to be satisfied with their choice and look to him for the result.

I think this trouble could be obviated if the consulting engineers would take a firm stand in regard to it. Let them be upon their dignity and be prepared to maintain hat this responsibility rests with them.

Yesterday we were testing the pumping engine for the Spring Valley Water Works. We had nothing to do with designing the engine. The plans were made and prepared by their own engineers, and yet the contractors were required to give a guarantee that the pump should perform a certain duty. The contractor is perfectly powerless; he cannot make it any better or worse than it is. He should try to make the machinery as perfectly as human skill can make it, and there his responsibility should end. When a contractor prepares and follows his own designs, then, of course, he is responsible for what he constructs. When the consulting engineer prepares plans and specifications, and these plans are sent out and bids are made upon them, that engineer, and no one else, should be responsible for the results. This particular point I want to call your attention to in regard to consulting engineers.

Referring to inspecting engineers I wished to bring out this point, that there should be a better understanding between inspecting and contracting engineers. They ought to be friends instead of being suspicious of each other. There should be no such thing as cringing on the part of the contractor toward an inspector. There should be no striving to hide things, which there is no reason to hide all. Especially in machinery, no work is entirely free from defects, but these may not prevent it from answering fully all its purposes. If work were perfect there would be no need of inspection.

In regard to contractors, I think they ought to take a higher stand

than they do. Ethics should control them in their business. We can all afford to tell the truth. Yet, what may be true in the morning may be a lie before night. I have often told a man in the morning that a thing was so and so, and by evening affairs would be in such a shape that he would tell me it was untrue, and yet I had had no intention of telling a falsehood. What I have said was perfectly true when I said it.

Inspectors ought to understand and sympathize with contractors who do their best. When they do, we shall have better work and better machines.

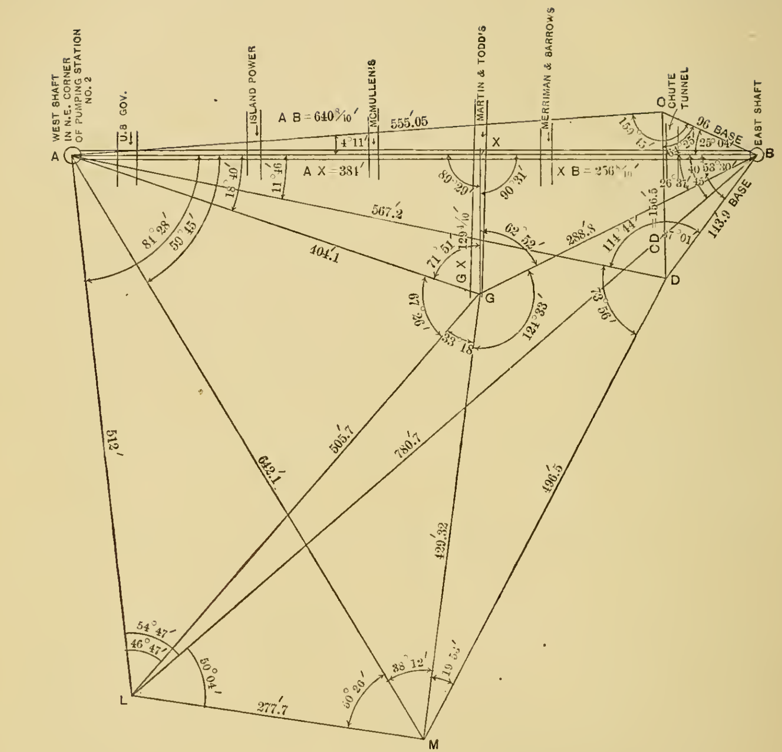
TRIANGULATION PREPARATORY TO ALIGNMENT OF A TUNNEL.

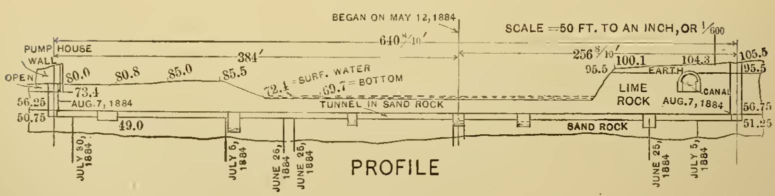
By Wm. W. Redfield, Member Engineers' Club of Minneapolis, Minn.

[Read before the Club, March 2, 1896.*]

In the spring of 1884, the Water Board of Minneapolis, Minn., decided to sink a shaft in the northeast corner of Pumping Station No. 2, commonly known as "The East Side Pumping Station," and situated on Hennepin Island in the Mississippi River; also to sink another shaft on the eastern shore of the Mississippi River, on Third Avenue Southeast, about twenty feet east of the east line of Main Street; and also to connect said shafts at bottom, by a tunnel; all for the purpose of conveying two 30-inch water pipes across the east channel of the Mississippi River. As every one familiar with the geology of Minneapolis well knows, the shafts successively pass through earth, limestone and sand-rock of a yellowish-white color, the latter easily worked with the pick, and very favorable for tunnel driving. The lower surface of the limestone ledge being nearly level, forms an excellent roof for a tunnel. In fact, the numerous tunnels for the tail-races of the various mills are nearly all driven immediately under this ledge. It was decided to made the shafts circular in shape and 10 feet in diameter; and the connecting tunnel, rectangular in cross-section and 8 feet 6 inches wide in clear, lined on both sides with a rubble wall 16 inches in thickness, and 5 feet 4 inches clear height, and floored with concrete 2 inches thick. The natural way in this work would have been to sink the two shafts to the depth desired, and with two points at one shaft in line with two similar points at the other shaft, to transfer each pair of points to bottom of their respective shafts by careful plumb lines, from which the tunnel alignment would be made. This would have been the *only* way possible at this tunnel if it had not been for the fact that six other tunnels were to be crossed at nearly right angles, their general elevation of water surface being fortunately below the level of the bottom of the tunnel proposed. Three of these tunnels carried tail water from saw-mills; another one was an abandoned tail race, as was also the old Government tunnel; and a sixth one was the tail-race of the Island Power Company, quite deep, having recently been lowered. Of these, the Martin and Todd saw-mill tail-race crossed nearest the center of proposed tunnel, and as it was desirable to let shafts and tunnel separately by contract, and in order to save time, it was decided to commence driving the tunnel a little before the shafts were

* Manuscript received March 6, 1896.—*Secretary, Ass'n of Eng. Socs.*


WEST SHAFT IN N.E. CORNER OF PUMPING STATION NO. 2
U.S GOV.
ISLAND POWER
McMULLEN'S
MARTIN & TODD'S
MERRIMAN & BARROWS
CHUTE TUNNEL
EAST SHAFT
A
B
O
X
G
D
L
M
A B = 640 8/10′
555.05
A X = 384′
X B = 256 8/10′
567.2
404.1
288.8
CD = 156.5
96 BASE
143.9 BASE
512′
642.1′
505.7
780.7
429.32
496.5
277.7
GX
81° 28′
59° 45′
18° 40′
11° 46′
4° 11′
89° 29′
90° 31′
62° 52′
71° 51′
124° 33′
33° 18′
114° 44′
73° 56′
54° 47′
46° 47′
50° 04′
50° 20′
38° 12′
25° 04′
40° 53′ 30″
26° 34′ 45″


BEGAN ON MAY 12, 1884
SCALE = 50 FT. TO AN INCH, OR 1/600
PUMP HOUSE
WALL
OPEN
640 8/10′
384′
256 8/10′
80.0
80.8
85.0
85.5
73.4
72.4 = SURF. WATER
69.7 = BOTTOM
TUNNEL IN SAND ROCK
49.0
56.25
50.75
AUG. 7, 1884
95.5
100.1
104.3
105.5
95.5
EARTH
LIME ROCK
CANAL
AUG. 7, 1884
SAND ROCK
56.75
51.25
JULY 30, 1884
JULY 5, 1884
JUNE 26, 1884
JUNE 25, 1884
JUNE 25, 1884
JULY 5, 1884

PROFILE

begun. Accordingly the Martin and Todd tunnel was selected as a means of access, and the tunnel proposed was to be driven simultaneously east and west from the saw-mill tunnel towards each shaft; these shafts did not reach the bottom of the rock for some days after the tunnel contractors reached and removed the sand rock below limestone at the bottom of each shaft. The task of providing alignment for the above, falling upon the author, he devised the system of triangulation as explained below, reference being had by letter or otherwise to the accompanying diagram and profile.

Points *A* and *B*, or centers of shafts, being located, two points, *C* and *D*, were established, and base-lines *BC* and *BD* were carefully measured; these being very short (96 and 143.9 feet respectively), *two* were chosen, as a check on each other; and it being at that time difficult to find any longer ones. Angles were observed as follows: *CBA, ABD, CAB, BAD, ADB, CDB, ACB, DCB.* From these elements *AB* was computed by two solutions from triangles *ACB* and *ADB*; *CD, AC* and *AD* were also calculated. This established the length of proposed tunnel to be 640.8 feet.

Next, to facilitate the entrance of a line up the Martin and Todd tunnel, a point *G* was placed at mouth of said tunnel in such position as to see therefrom up the tunnel. Auxiliary points were also placed at *L* on Hennepin Island, and at *M* on the east bank, both some four hundred feet down stream. The following angles were then taken: At *A: BAG, BAM, BAL.* At *B: ABG, ABL.* At *G: AGB, BGM, MGL, LGA.* At *L: ALG, ALB, BLM.* At *M: DMG, GMA, AML.* From these various angles and the proper triangles the sides *AG, BG—AL, GL, BL—AM, GM, DM, LM* were computed and the values found as indicated on diagram. This necessary preliminary work was prepared in the office beforehand, after doing the field work. Then on Sunday, May 4, 1884, when the mills were shut down, an indefinite line was run from *G* towards *X* and the angles *AGX* and *BGX* measured. Then, during the week following, from the angles *BAG, AGX, ABG, BGX,* and the sides *AG* and *BG* were computed the sides *AX, BX,* and *GX* (two solutions being obtained for the latter from the two triangles *AGX* and *BGX*). *GX* was the distance required to proceed up the saw-mill tunnel before beginning the work; the angles *AXG* and *BXG* (together necessary to be 180°) gave the proper angularity to turn at *X* from line *GX*, after measuring *GX*. *XA* gave total distance to proceed westward and *XB* total distance to proceed eastward to reach each shaft. The second set of calculations having been finished, on Sunday, May 11, 1884, the transit was again placed at *G*, and the angle *AGX* turned off, sighting towards *X*; the calculated distance *GX*, or 129.4 feet was measured

carefully on said line to point X, which point was thus established. Then the transit was placed at X and the angles AXG and BXG successively turned off, thus enabling a point on a line of proposed work to be placed both east and west. Next morning, Monday, May 12, 1884, work was commenced and diligently prosecuted to completion. The shafts were begun somewhat later, and finished to bottom of rock; the east one on or about August 7, 1884; the west one somewhat later, and the tunnel reaching both ends, as stated before, some days before August 7, 1884. The tunnel and shafts carry at present one boiler-iron pipe 30 inches in diameter in tunnel and a cast-iron pipe 30 inches in diameter in shafts, and placed on the south side of tunnel and shafts, leaving room for an additional one on the north side, whenever required. The accompanying diagram and profile give a few statements showing rate of progress and datum heights. At present date the pipe and tunnel and shafts have not ceased to give satisfaction. It might be of interest to state here that the pipe in tunnel rests on rollers at a suitable distance apart, bearing on iron plates, and near the middle of tunnel the pipe is provided with a sliding joint, like a stuffing-box, to take up any longitudinal expansion or contraction. The pipe at top of each shaft reduces to a 24-inch cast-iron pipe. The water comes from a computed 10,000,000-gallon pump, but ordinary daily work runs from 4,000,000 to 7,000,000 gallons.

Editors reprinting articles from this journal are requested to credit both the JOURNAL and the Society before which such articles were read.

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THE STANDING OF ENGINEERING AMONG THE PROFESSIONS.

ADDRESS OF J. S. KEERL, RETIRING PRESIDENT OF THE MONTANA SOCIETY OF CIVIL ENGINEERS.

[Read before the Society at Helena, Montana, January 11, 1896.*]

IN the past three decades, the very liberal education afforded by our public schools, and other institutions of learning, has received a full endorsement through the achievements of the present generation; not alone throughout the commercial world, considered generally, but more especially among those whose professions are based upon the applied sciences and upon their varied application to the practical questions of life and business.

Within this relatively short period, all the sciences and arts, and the collateral professions, have made herculean strides, not only in their own special advancement, but collectively, in advancing the progress of civilization, and in a much greater ratio then had ever before been achieved, in any quarter of a century, in the world's history.

The legal and medical professions have accomplished grand results. The opinions handed down by many eminent and patriotic Judges, and the learned arguments of Attorneys, take their place in the general advancement of mankind. The names of Pasteur, Koch, and others, of the medical profession, are now household words, and monuments in

* Manuscript received March 14, 1896.—*Secretary, Ass'n of Eng. Socs.*

themselves, by reason of their great discoveries. The ambition to understand life in its complex and varied conditions, when actuated by the desire to relieve suffering humanity, is surely one of the most worthy and honorable that can ever stimulate the genius of man.

These noble professions, the legal and the medical, are the two oldest, and the most fully recognized and appreciated by the public at large. Their antiquity, as well as their accomplishments and assertiveness, have won for them their well earned recognition and their fitting emoluments.

There is another calling, a profession not nearly so old, in fact an infant in view of the antiquity which surrounds the history of those above mentioned; and yet during its short existence, it has made such phenomenal strides, that, if judged from what it has accomplished, one would expect to find it prematurely gray. A profession which many savants have pronounced the only one which does not live by the contentions, miseries, and distresses of humanity, but alone deals with endeavors to advance mankind to the enjoyment of a higher civilization, by subduing, diverting, and directing the forces of nature to the uses and benefit of man—such is the engineering profession.

Through a review of history we must be impressed with the fact that ignorance, and its ever present boon companions, superstition and arrogance, have been the chief and most unflinching enemies to all progress and to all efforts ultimately designed for the benefit of mankind. When we recall the lives of Galileo, Voltaire, Smeaton, Watt, Stephenson, and even one who lived as late as Fulton, we must be impressed with the devotion and heroism which these men displayed, especially in times when to proclaim a new principle evolved, or a practical application or a science secured, meant persecution for witchcraft. They, as the intellectual lights of their age, knew full well their duty, the enlightenment of the world, and its redemption from savage lethargy; and accepted the task even at the threatened sacrifice of their lives.

Men like these, if we could have been honored by their existence in our age, would be classed as Engineers, in their several specialties. They stand now upon the pages of ineffaceable history, as the fathers of the applied sciences, and as such, we owe them the reverence due the founders of the engineering profession. The names I have mentioned are but a few of those, who, by their fortitude and by their desire to advance the cause of civilization, were willing—yea anxious, to sacrifice themselves upon that altar, which in their day, meant persecution for a principle.

The heritage which they have left us possesses a foundation broader and more deeply seated than that of any other profession. Its resources are illimitable; and the most fertile imagination fails to convey a fitting conception of its future triumphs.

Such names as the Roeblings, Holly, Eads, Flad, Howe, Trautwine, and others, are ever in our minds, as stimulating incentives to greater effort. Their work has been grand in conception, and practically faultless in execution. The majestic bridges, which carry millions of human lives and untold tons of freight across deep and yawning chasms; the tunnels, miles in length, which have removed the barriers of mountain fastnesses to commerce; and the harnessing of the mighty Niagara, and other rivers, all show the accomplishments of the engineering profession, and suggest the possibilities of its ever grander future.

While, as Engineers, we have no fear of the results from a comparison of our achievements with those of the other professions, yet, as one who has served something like twenty years in the varied branches of engineering, I would ask whether we have secured from the public that full recognition and emolument which the importance of our profession would seem to justly demand.

In our own State it might appear, at times, that our want of interest and aggression in political life had withheld from us a proper recognition in public affairs. In reviewing our history we find that Engineers, and even Architects, are not considered useful or necessary, as members of a Capitol Site Commission, or of even a Capitol Building or Irrigation Commission, the appointing power evidently preferring to make the Architect and Engineer, simply an employee, or subordinate to the Commissions. Bills have been before our Legislature, upon several occasions, which also failed to recognize the Engineer as a proper person to place upon State Commissions dealing with engineering questions. In a proposed bill for the purpose of establishing a comprehensive irrigation system for the State, more than 75 per cent. of the work to be done by the Commission would have been of an engineering character; and yet the framers of this bill would recognize none of the arguments made in the hope that they might appreciate the importance of having some engineering ability in such a board to suggest methods of procedure and plans. The public, as a class, seems to regard an Engineer as one better fitted to take directions, and to be in a subordinate position to a Board or Commission, than to sit with such a body as a full member, and have a full voice in the deliberations and in the framing of an intelligent plan of procedure.

From my standpoint, I fail to see any reason why the Engineers of our day, who are better educated, upon the average, than members of any other profession, and who must devote a longer time to the practice of their profession before they are deemed sufficiently proficient to take charge of important works, should not be fully recognized in public affairs, and especially upon those Government and State Commissions where their special training and knowledge would be of great service to the public.

Our Society should have noble aspirations upon such subjects; and I have deemed it proper to bring these questions to the attention of our members, in the hope that they might engage some earnest thought and inquiry upon your part, and at this, or some future occasion, a general discussion. An intelligent public must acknowledge that the Engineers of this day are as patriotic to their country, and as loyal to their profession, as those grand men of history to whom we are indebted for initiating our calling; and I most sincerely trust that the Montana Society of Civil Engineers—a most worthy and honored representative of the engineering profession—will ever use its voice and influence in earnest endeavors, exerted in the interests of the proper development of the illimitable resources of the State of our adoption, and for the fitting recognition of the engineering profession, which should, of right, be foremost in the attainment of the grandest results.

ANNUAL ADDRESS AS PRESIDENT OF "THE TECHNICAL SOCIETY OF THE PACIFIC COAST."

By George W. Dickie.

[Read before the Society, February 7, 1896.*]

The Society having in the usual manner expressed its desire that I should continue for another year as its executive head, I must take the opportunity that the occasion offers to express my appreciation of the honor conferred on and the confidence reposed in one who is not by any means the best qualified member of this society to occupy the place of honor.

In taking up this work for another term I desire to express my obligation to the late Board of Directors for their faithful work in connection with the varied interests of our society. By their efforts we find ourselves, at the beginning of another year, in a very much improved financial condition, with a fair prospect of being entirely rid of a debt which has hampered the work of the society for several years.

The arrangement made during the past year, whereby our society joined the Association of Engineering Societies, has enabled us to resume the publication of our transactions in the Journal of that Association. It is hoped that this action will be the means of stirring up a more lively interest among the members, both resident and non-resident, in the work of the society.

Of late some difficulty has been experienced in getting members to prepare papers to be read at the regular meetings of the society. This is unfortunate, and a strong effort should be made this year to remove this difficulty. The main object of the society's existence is to provide the means of permanently recording for mutual benefit the experience of the members in the various branches of our profession. I am well aware of the difficulties that beset busy professional men, and the lack of leisure that prevents many able men from recording their experience for the benefit of others, and I must also acknowledge with shame that many of our brightest professional men are bound by force of circumstances to labor on without respite on work that other men get the credit of, and their silence in regard to the work they are doing is the price they must pay for the chance to earn a living. It is this shameful condition, prevailing to so large an extent in this country as compared with other countries, that makes the transactions of foreign societies so much richer in practical experience than our own. I find that corporations, usually very stupid, and therefore

* Manuscript received March 23, 1896.—*Secretary, Ass'n of Eng. Socs.*

very selfish, are possessed with the stupid and selfish idea that because they employ an engineer to plan or carry out some unusual work for them, that the experience he has gained in so doing is their property and not his, and he must on no account give any of it away for the benefit of his professional brethren, for, might it not be used for the benefit of some rival corporation just as stupid and selfish as they are? Our transactions in the past years of the society's life have compared favorably with those of any other society of its membership in this country; but in order to show that we are growing in experience as well as in members, the record of our doings must keep pace with our advance in the practice of our profession.

While speaking of the recorded work of this society, I have to express my own sorrow, and in doing so I am sure that every member of this society feels the same deep regret, at the announcement made in the last number of *Industry* that that monthly is to be abandoned. I have been afraid of this termination to the life of *Industry* for some time, as I knew that Mr. Richards was carrying a greater load than his strength was equal to. That journal has been practically all his own work, and only those who have done such work can realize what that means. *Industry* did much for this society, and we shall feel very keenly the want of the stimulus that comes from the help of such a journal. I trust that some way may be found whereby we may still have the benefit of the recorded experience of our able member and ex-President, Mr. Richards.

The past year has been one more productive of experience than profit to the engineer. Many of our members have had to cultivate the virtue of patience and practice the science of waiting for something to turn up to a far greater extent than was good for them or the profession. Still, this State is immensely rich in natural resources and most of these resources are as yet undeveloped. Capital in the future will be invested with greater care than it has been in the past. Better and more permanent engineering works will be demanded in the near future in all branches of industrial development, and I feel certain that out of the present financial and industrial depression, lasting good will result to the engineering profession.

The advances that are being made both in the chemical and mechanical branches of mining engineering are of great importance to the Pacific Coast, and more activity is now apparent in our mining industries. This will give fresh opportunities to our engineers, opening up new fields for enterprise.

The electrical reduction of ores, the transmission of power by electricity from its natural source to the point where it can be profitably applied, the generation of electric currents for all purposes of light and

power still continue to give our mechanical engineers and electricians all the opportunities they can utilize for advance in an art that is just beginning to show its possibilities. The element of mystery ever present in all applications of the electric current as a means of transmitting power, has made it the ideal source of everything miraculous to the public. The great losses that so often result from its application to purposes unsuited to the nature of electricity, being invisible, do not strike the man who pays the bills so forcibly as a leaky steam or air pipe, or a bursted hydraulic main; so we often find our old and faithful pneumatic and hydraulic servants discarded to make room for the bright, new and lively electric man of all work. Yet the cost of doing the work is not always decreased by the change. The general opinion to-day appears to be that it will not be long before all the applications of power for the production of mechanical movements will be made through the electric current as a means of transmission. I do not concur in this opinion; but I believe that in all mechanical movements which the electric current naturally can produce without too much gearing, it will be the medium of transmission of the future. Where the transmission can be properly and economically made by the means of electricity it will be made and improved as experience develops it; but many operations now being attempted through electricity as a means of transmission will, after the limitations of this agent are better understood, be abandoned and the older methods will find many places where they can give better service than even the harnessed lightning. So I would not advise our younger members to neglect everything else for the study of electricity. There will always be a place, and a large one too, for thermo-dynamics, pneumatics, hydro-dynamics, as well as electro-dynamics, and he who puts all his faith in the universal efficiency of copper wire to perform every mechanical function, may some day receive a shock, and be forced to admit that even the electric current will not always go in the direction that is desired.

Our society has just made a beginning in a very profitable field of engineering that I trust may be extended so as to embrace all materials that are natural products of the Pacific Coast. I refer to the committee that we have just appointed to gather data and formulate it into a report on all the physical properties of our Pacific Coast timbers, with a view of providing information that can be accepted as trustworthy by all those whose practice requires an extended use of these materials. This committee being composed of both scientific and practical men who have already given much time and thought to the subject, their report will no doubt be accepted as authoritative, and help the extended use of this valuable product of our coast.

I should like very much to see a similar committee appointed to

report on the properties and values of the various building stones both natural and artificial, found or manufactured on the Pacific Coast. Correct data on this important subject is very much needed by all those who in their practice have to employ such materials and I trust that we may soon see our way to take up this subject.

As a body of men whose success is entirely dependent upon the commercial and industrial prosperity of that portion of the United States facing the Pacific Ocean, what encouragement and hope can we gather from the present indications of what the future has in store for the Pacific Coast? I base what hope I have for the future prosperity of the Pacific Coast not so much on our undeveloped natural resources, for they will never develop themselves without man's labor backed and supported by his enterprise, as on the evidences that I see to-day among all classes of business people of an awakening to the realization of the conditions that confront us, and a common desire on all sides to get together for intelligent study of all commercial and industrial problems that must be solved before permanent prosperity will begin.

We have reached a point in the history of this community when our state and municipal legislation must perform other functions than that of planning ways and means of increasing taxation. Industries that naturally should flourish among us should be fostered and sustained by wise laws. When we discover that the tax-gather is driving what should be a great industry away from our shores to another state or another nation, which is wise enough to keep the tax-gatherer away from a business that when taxed in one place simply moves to another, we had better consider whether we had not better keep our trade and forego the taxes than try to gather taxes and lose both.

That these questions are now in men's minds, not yet clearly, but getting brighter as they are thought over, is my hope for the future. The recovery is to be slow, and I think painful, because the disease is deep rooted. Our people must learn that commerce and industry is the foundation for the prosperty that abides. Speculation and debt is what we have been trying to subsist upon, and the man who has the biggest debt among us is the one we serve and acknowledge as king. This is not a fancy of mine but a fact, and to reverse that fact is the work that the men who seek to save the Pacific Coast must accomplish or fail.

EXPERIENCES IN AN ENGINEER'S PRACTICE.

By Walter P. Rice, Member of the Civil Engineers' Club of Cleveland.

[Presented before the Club, February 11, 1896.*]

In making the Petrie Street bridge improvement, the city of Cleveland constructed a large fill 60 to 70 feet in height across the valley, and a plate-girder crossing over the railroad tracks. The brook in the bottom of the valley had to be taken care of by a culvert. It was during the winter, and at a time when the Chamber of Commerce was passing the usual resolutions about helping the poor, and the cry was to afford work to unemployed men.

We made two designs, one for a stone culvert and one for a cast-iron culvert 6 feet in diameter. The argument was used that in winter it was difficult to get stone, and this meant delay; and the city wanted to adopt methods which would put the greatest number of men to work immediately. It was finally decided to go ahead with the cast-iron culvert. The pipe was 6 feet in diameter and about 2 inches thick, cast by The Variety Iron Works Co., of this city. I am not sure whether it was in 6- or in 8-foot lengths, but think it was in 8-foot lengths. When we came to investigate the question of proper thickness for this pipe, we could find no information in regard to the use of pipe of that diameter, and we were at a loss to form a correct estimate of the proper thickness. We took what we thought to be an extreme precaution and considered pressure in certain directions on the assumption of hydraulic pressure. After estimating the pressure, we found plenty of formulæ with regard to internal pressure, but could find nothing satisfactory as regards resistance to external pressure. We used the best information at hand, in the shape of a German formula, and concluded that a thickness of 1½ inches was ample. We added what might be called a factor of ignorance, and made it 1¾ inches; and the manufacturer added another factor to increase the amount of his bill, and it was cast almost 2 inches thick.

The foundation under the entire fill was very good. We struck one bad place at the edge of the fill, where the soil was soft. I left directions to take out all the soft material and refill with wet sand, tamped in layers until sub-grade was reached, and then to put concrete on top of that. This I supposed was done, although I was not there at the time. After the foundation had been prepared, a bed of Portland cement

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concrete, 9 feet wide and 18 inches thick, was laid, the pipe put in place, and the concrete carried up to the spring line, where it was 9 inches thick on each side of the pipe. From this point the concrete was finished tangent to the circumference. Orders were given to have the fill deposited in layers and tamped for a width of not less than 25 feet over the culvert, and I have no reason to suppose that it was badly done. Some time after the fill was constructed, in making an examination of the interior of the culvert, which is several hundred feet long, I found four lengths of pipe all adjacent or contiguous, cracked longitudinally top and bottom. For instance, there was a longitudinal crack on the top and bottom, running the entire length of four sections. Upon taking measurements, I found that there was a difference of four inches between the horizontal and vertical diameter of the pipe. We put in temporary bracing until the fill got through settling. The entire fill was made with more than usual care, and as the settlement was not at all excessive I cannot account for the failure of these four lengths. If they had not been adjacent to one another I might have thought that it was due to flaws or initial strains in the material; but the pipes were contiguous. The material was first class and subjected to the usual transverse tests. I can only make this one supposition: The fractured pipes were in the neighborhood of where we found the pocket of soft material. The inspector claimed to have had all of same removed, and there was at least 3 feet of fine sand and 18 inches of Portland cement concrete under the pipes at this point and the material over the culvert was tamped before the fill was made. The law of transmission of pressure in a fill of this sort and the law of resistance of the cast-iron ring under such conditions have always been interesting questions to me. What is the law of pressure? What is the law of resistance under these conditions? Apropos, I observed a curious thing with regard to external pressure in the current apparatus used when I was with Col. John M. Wilson on the gauging of the Cuyahoga River. It was simply an annular ring or submerged float with air space. It was sunk in rather deep water, and being made of tin, it collapsed under the pressure. In that case there was pressure all around the circumference. When the submerged portion was brought to the surface, it had been flattened, producing three sides of a perfect pentagon. The entire question is one that is extremely interesting to me, and one upon which I have been able to obtain very little light.

Incidentally, in connection with this, I might mention that on account of conflict with property holders at Petrie Street fill, the drainage or storm-water sewer which we had intended running down the side of the hill, along the edge of the city's slope right, had to be located in the fill itself nearly 60 feet above the brook into which we expected to

discharge. We used a drop man-hole, similar to an earlier design by Mr. Force, except that the foundation and details were somewhat different. So far as I know, this is one of the highest in existence, being 70 feet high, with a series of steps of stone flagging to break up the water every 4 or 5 feet all the way down. We used steel I-beams and concrete for the foundation of the drop man-hole, and the connection with the culvert was made with an iron pipe. Two sleeves were provided in this pipe, and clay was puddled around the joints to allow for any inequality of settlement between the culvert and drop man-hole. After settlement, we closed up the sleeves with Portland cement.

We had some trouble with settlement of pedestals on the Central Viaduct, in the neighborhood of Central Way. Strange to say, the amount of settlement gradually decreased towards the river. It finally assumed such proportions that I thought something must be done. I think the maximum settlement was in the neighborhood of $9\frac{3}{4}$ inches. A great many of the bents had settled, and it became noticeable on the bridge itself. Water stood on the bridge floor, otherwise it would not have been noticed by the public. We desired to raise it, and did not want a lot of sensational articles in the newspapers; so we undertook to raise it with our own bridge gang without making it public. We secured the money under some very harmless resolutions. The newspaper men were there, but being for repairs they did not comprehend it. A careful profile was made, showing the exact settlement. Instead of bringing them all up to the grade line, we brought them two-thirds of the way up, and at a very slight curvature that would not be perceptible to the eye, and then calculated to raise each one up to that curve. I think we raised 18 bents, and this was all done with travel (motor cars, etc.) going on overhead. We had a total height of 83 to 85 feet from cap of pedestal to roadway, and 108 tons to lift on each leg of the bent, the leg being composed of two channels latticed. It was almost impossible to get any purchase anywhere to make such a lift. We had a stone cap 5 feet 8 inches square, with a beveled edge, and only 12 inches, including a 4-inch wash on each side of the post, to get our purchase for the 108 ton lift. We finally decided on a method, using very simple apparatus. Short upright wooden bents were erected upon blocks on the stone caps and wooden cross-caps on top of these supported the I-beams which carried eight rods $2\frac{1}{2}$ inches in diameter. Reinforcing plates with a $5\frac{1}{2}$ inch bored pin-hole were riveted to the web plates of the post at a convenient distance below the I-beams and match holes were then bored in the webs with a tool made especially for the purpose. A $5\frac{7}{16}$ inch pin was slipped into place, cast-iron bearing-blocks on top of heavy channels were fitted up under the pin close to the webs of the post, and the channels then connected to the rods mentioned. The

men worked on a platform, and each one gave a certain number of turns to the nuts on the eight vertical rods. As fast as a bent was raised 1 inch a steel plate was slipped in, and when the proper height was reached cast-iron bases were put in place. Of course, we had to make certain adjustments in the trusses as the work progressed, but the entire structure was lifted without attracting attention. We were, however, working in very tight quarters. After the work was done, the city kept track of it and found some further settlement. This led to making borings which developed a rather strange state of affairs. We found, for instance, at one of the pedestals, 3 feet of sand, 4 feet of cinders and water, and 4 feet of clay and sand, in which the footing rests; then we found 10 feet of logs, soft clay, water and peat; 6 feet of sand and soft clay; 4 feet of very soft clay and logs; 3 feet of clay and very light sand; 4 feet of clay and sand; 1 foot of clay and water; and then coarse gravel and water. The borings in the neighborhood of the other pedestals were very similar. The indications all seemed to point to an old channel of the river. The same question of the transmission of pressure through soils comes in again. If that pedestal has gone down 9 inches, what action has taken place? How does the clay act? How is the pressure transmitted? The foundation is in the clay. If there is a hard stratum below and a soft stratum between, does the top stratum of clay act like a beam? Is that possible? In other words, if we have a fairly firm stratum of clay and then soft material superimposed upon hard material, is it possible that, as the pedestals sink down, the surface rises on account of lateral pressure in the direction of least resistance? That the material rises at a point of circumference outside the pedestal and depresses under the same? Is it possible that such a stratum can act in a manner similar to a beam? Under such conditions, which is the wiser course—to attempt to reduce the pressure by spreading further, or to break through the solid stratum and attempt to go down to a firmer bearing?

THE PRODUCTION OF DIPHTHERIA ANTITOXIN.

BY DR. THEOBALD SMITH, PATHOLOGIST OF THE MASSACHUSETTS STATE BOARD OF HEALTH.

[Read before the Boston Society of Civil Engineers, February 19, 1896.*]

THERE is to-day among the various branches of scientific research a solidarity which makes it possible for me to be present here to-night to speak upon a subject of pure biology quite remote from the daily interests of your own profession. The biologist deals with what many of us choose to call the principle of life, whose activities do not as yet admit of that nice computation, that clever accuracy, realizable in the departments of physics and chemistry ; and yet the mysterious processes of life are after all explicable and measurable only by the same standards and units which are common to all natural science. Life expresses itself to us in physical and chemical phenomena, and the progress of biology is marked by the gradual adoption of chemical and physical units. Here is the common ground of all research. The practical relationship between biology and engineering in the field of sanitation is too well known to bear more than a passing notice. The progress made in the prevention of disease from the biological standpoint exerts a strong pressure upon the views and methods and products of the builders of great cities, of great water-works, and of stupendous sewers. I shall not, therefore, in view of this close relationship, hesitate to present the details of the subject before us as minutely as I would to a body of specialists devoted to biology in its medical and sanitary aspects, trusting that this attitude will meet your approval.

The old theory which appeared with the discovery of bacteria, twenty or twenty-five years ago, insisted rather upon the mechanical action of bacteria, their obstruction of the bloodvessels and of the lymphatics of the body; but in the course of the great many investigations which have been made since that time we have come more and more to the theory that bacteria act not through merely mechanical effects, but that they act through chemical substances which they either manufacture or which are present in their bodies, and which are to the animal organism poisons—some of them very virulent in their nature.

To ward off the injurious action of bacteria, the body has at its command certain defences, certain means of protection. It has, in the

* Manuscript received March 19, 1896.—*Secretary, Ass'n of Eng. Socs.*

first place, the opportunity to destroy the bacteria themselves. In the second place, it has the opportunity of neutralizing or destroying their poisons. These poisons are known to-day familiarly under the name of toxins. We have, therefore, the two forces, the bactericidal and antitoxic effects, which are now being investigated quite exhaustively. In point of time the bactericidal was first observed. Metchnikoff, the great Russian biologist, is the most prominent figure associated with the evolution of our knowledge of bactericidal forces. It is he who first presented that doctrine, familiar to all of you undoubtedly, of the fight between the animal cell and the invading bacteria. He traced the development of these activities, which he called phagocytosis, through the lower invertebrates up into the mammals, and up to the present time he has been defending the theory of phagocytosis against the encroachments of another theory which I will present this evening. In spite of his brilliant researches and his advocacy of the theory of phagocytosis, there have come to the front studies which show that the bacteria are not always destroyed within the cells which take them up, but that the forces which destroy the bacteria in the body are largely extra cellular.

The knowledge of antitoxic forces could only be developed after the study of bacterial toxins had made some progress. It was not until 1888 that toxins were first definitely studied by Roux and Yersin, of the Pasteur Institute at Paris. These investigators showed that not only the diphtheria bacillus itself could produce diphtheritic affections and paralysis in animals, but that the culture fluid in which these bacilli had multiplied and from which they had been removed could produce a fatal toxic disease. Here we have demonstrated for the first time the existence of bacterial poisons which may act quite independently of the germs which produced them. These poisons could be precipitated from the culture fluid, dried and redissolved in water without losing their pathogenic properties. These were destroyed by heat, sunlight and a variety of other agencies. This important work furnished medical science a satisfactory explanation of the symptoms of diphtheria in man. A local vegetation of bacteria in the throat to produce such pronounced constitutional disturbance must act through some soluble poison absorbed into the body from the seat of the local disease. The extremely poisonous nature of this bacterial product may be appreciated when we bear in mind the fact that since then cultures have been found so virulent as to prove fatal to guinea pigs when only .005 of a cubic centimeter of the filtered fluid is injected under the skin.

In 1889 another bacterial poison was discovered, which proved even more fearful in its effect on animal life than the poison of diphtheria. Kitasato, a native of Japan and a pupil of Koch, has done

more than any other in making us acquainted with this poison. The disease known as tetanus was shown by him to be due to a bacillus of peculiar character, upon which I need not dwell here. After having mastered the difficulties surrounding its isolation from wounds, he found that even after the culture fluid had been passed through a Chamberland filter in order to deprive it of all living tetanus bacilli, a very minute dose was sufficient to produce in various animals the whole train of symptoms characteristic of tetanus. But, more than this, the blood and serous fluids of those animals which succumbed to this poison contained enough of it to produce the same disease in a second set of animals.

We have thus the remarkable phenomena of two diseases produced without the presence of the germs, simply by their products. And what are these products? While Roux and Yersin regard them as enzymes, the German observers have regarded them as albuminous in nature and given them the name of toxalbumins. I think there is no doubt that they are albumens and not enzymes or ferments, because we can graduate the dose very carefully which will destroy a guinea pig, and this dose remains constant for months in the laboratory and is used as a standard in testing poison for the antitoxin serum. The toxalbumin of tetanus is quite sensitive to light and to temperatures above 55° C. It loses its virulence when dried at the temperature of the blood in the thermostat. It remains unaffected when water is added, but is speedily destroyed by chlorhydric acid in less than one-half per cent. solutions.

Among the many pathogenic bacteria which have been studied these two stand out pre-eminently as toxin-producing. Though poisons are demonstrable in cultures of most if not all pathogenic forms, their action is feeble as compared with these. This fact, togther with certain other differences, emphasized the division made some years ago by Koch between the infectious and the toxic diseases. The bacteria producing the infectious diseases multiply within the organs of the body, whereas those which produce the toxic diseases remain outside of the body; in the throat in diphtheria, in the wound in tetanus, and by the diffusion of their poisons manufactured in these places completely subdue the resistance of the body.

So much for the investigation pointing to the existence of soluble poisons which leave the bacteria and diffuse themselves throughout the culture fluids which we employ. In 1890 the doctrine that antitoxins exist in the body first became known through researches made in Koch's laboratory by Behring, who is now known to all of you as the real discoverer of the principle of antitoxic substances. In December, 1890, Behring and Kitasato announced the new principles as deduced from their experiments with the poison of tetanus as follows:

The blood of rabbits made insusceptible to tetanus possesses the power to destroy the poison of tetanus.

This power resides in the extravascular blood as well in the blood serum free from cells.

This power is of such permanent nature that it remains active in the organism of other animals. It is thus possible to produce pronounced therapeutic effects by the transfusion of blood or serum.

Thus the principle was established, but there were a good many practical difficulties in the way of its immediate practical application, and it was only several years ago, I think in 1893, that serum was produced in sufficient strength to be used in therapeutics. At first sheep were used for this purpose, but the antitoxic power of sheep's blood remained quite low. Then horses were used, and they are still used to-day because they produce a very effective serum, and because they can stand the withdrawal of a large amonnt of blood.

In regard to the choice of horses, there is of course considerable difference in their behavior towards the treatment which produces antitoxin. The high-bred horse, the sensitive horse is an animal unsuited for this purpose, and it seems that those that are very stupid are also unsuited for other reasons. The high-bred horses will die from the effects of toxin if the dose is graduated a little too high. Horses of the other type do not show any reaction, do not care about the quantity of toxin injected, and consequently do not furnish any antitoxin that is worth preserving. The method as practiced on the horse is simply as follows: An animal is treated with the poison of diphtheria for from six to eight months, with increasingly large doses of toxin, until his blood yields the desired strength of the antitoxin.

The toxin is nothing but a broth culture of the diphtheria bacillus, from five to fifteen or twenty days old, from which the bacilli have been removed by filtration through a Chamberland filter and the clear fluid used for the injection. The ordinary culture flask which we use is one of this shape which I show you. This shape is chosen so that we may get a large surface of fluid in contact with the air which the diphtheria bacillus needs in the production of toxin. These flasks were devised in the Pasteur laboratory, to permit the suction of air through the flask while the culture was growing. It was thought that the bacteria needed oxygen plentifully, and consequently an aspirator was attached to this end and the air was drawn through. It has been found, however, that this is not necessary, and, as a matter of fact, the continuous current of air is injurious. The workers in the Pasteur laboratory obtained, apparently, a very weak toxin. We now use toxins ten to fifteen times as strong, largely because we have improved upon the methods which they suggested.

Now let us turn to the antitoxin. When the horse has been treated with the toxin subcutaneously for from five to eight months he acquires an immunity to the poison and can stand larger and larger quantities. There is always some swelling at the point of inoculation and a slight rise of temperature. But as the dose increases, as he becomes more accustomed to the poison, the temperature reaction is feeble and the local swelling disappears, so that a horse can stand at one injection enough toxin to kill an army of 10,000 guinea pigs, and can stand a dose of toxin which would kill probably 15 or 20 horses if that dose were divided among such as had never been under treatment.

There is some change, therefore, which the system undergoes, by virtue of which the blood is enabled to neutralize the toxin which is injected into the body. When after a certain number of days following the largest dose which we have given, the blood is drawn, allowed to coagulate, the serum drawn off from the clot, and this serum tested, it will be found that it can neutralize a large quantity of the poison.

The drawing of the blood is a very simple process. The two external jugular veins are very near the skin in the horse. A trocar and canula is used. This one was devised in the Pasteur laboratory in Paris. It consists of this canula or tube through which passes this pointed trocar. A little incision is made through the skin, this trocar with canula is forced directly into the vein through the incision and the trocar then withdrawn. The blood will flow out through the canula and rubber tube connected with it into jars prepared for the purpose. The horse will pay no attention to the operation but will continue to eat the oats offered him while the blood is being collected. I have drawn on an average four quarts or litres at a time. The wound is closed with a few pins. The horse shows no signs of disturbance at any time after the bleeding. I should say here that every operation is conducted under the most careful antiseptic precautions. All the apparatus we use is steamed first or else heated in a hot air oven to a temperature of 150° C. if it can stand that. All our glassware is heated to that temperature. That which does not stand dry heat is boiled, and all instruments and tubing are boiled or steamed, in order to destroy all adhering bacteria.

The blood is allowed to stand for twenty-four hours, after which time a considerable quantity of serum has gathered above and around the clot and this serum is drawn off. In twenty-four hours after that another lot is drawn off, and in three or four days the whole serum has been collected.

This is next tested as to its efficacy. All serum must undergo this test before it can be used as a remedy, because it varies in strength from time to time, sometimes quite unexpectedly, to the disappointment of the

bacteriologist. The test has been brought to quite a considerable degree of accuracy by Behring. He adopted a certain unit, which is simply this. Ten times the dose of the toxin, fatal to guinea pigs of a certain weight (300 grammes), is mixed with a certain quantity of the serum, and this mixture of serum and toxin is injected under the skin of the guinea pig. If no local swelling appears and if the guinea pig remains active and shows no disposition to become ill, then that toxin, ten times the fatal dose, has been neutralized in some way or other by the antitoxin, and the quantity of antitoxin used is considered as one tenth of a unit. In actual practice we have been enabled to raise the antitoxin to such a degree of efficiency that .001 c. c. of the antitoxin would neutralize ten times the fatal dose of toxin. That is to say, if we mixed .001 c. c. of serum with ten times the fatal dose and injected it under the skin of a guinea pig, that pig would show not the slightest indication of any local disturbance.

I have brought some of the serum with me. It is as you see a pale amber fluid of great clearness. This bottle contains 10 c. c. and each c. c. contains 100 antitoxic units. This other bottle contains 20 c. c. and is half the strength of this. This is the strength usually sent out from the Pasteur Institute in Paris, but many horses will produce a stronger toxin, and of this, to produce the same result, only half the dose has to be injected.

We have now before us the vexed question concerning the nature and mode of action of antitoxins. The first theory which suggested itself to Behring is that of direct neutralization of the toxin by the antitoxin. When the fatal dose of poison and the serum are mixed in a certain proportion and the mixture injected into a susceptible animal, no effect, either local or general, is noticed. When the amount of serum in the mixture is decreased, local indurations appear, and when still smaller doses are used the injected animals succumb.

When the diphtheritic poison and the antitoxic serum are injected separately in different regions of the body, the latter some hours earlier, from thirteen to fourteen times this quantity of serum is needed to prevent any local indurations, and from five to six times the amount simply to prevent death. In spite of this apparently very definite evidence that the antitoxin neutralizes the toxin in this chemical sense, and thereby destroys it, observations are not wanting which militate against it. Roux discovered the important fact that when a mixture of the antitoxin and the toxin which has no effect on normal guinea pigs be injected into those which have been previously immunized against Asiatic cholera, the fatal effect of the apparently neutralized poison reappears. Similar results were obtained when guinea pigs had been exposed to other bacterial poisons. Behring has also observed a fact

which seems to contradict the neutralization theory. In the case of horses which were undergoing immunization he found that animals became after a time sensitive to a quantity of poison which a little of their own blood would promptly neutralize in a test tube. That is to say, when injected under the skin of another animal it would produce no result, while they themselves, that yielded this blood, became very sensitive. Evidently we are dealing here with factors which appear simple but are really complex, and the contradictory evidence concerning their theory of action must be attributed to a deficiency of knowledge which time will undoubtedly make good.

Without any stable theory of the action of antitoxins, it might appear useless to discuss their nature at this time, and I shall content myself with the simple statement of a few hypotheses. The specific nature of these protective substances, in virtue of which the antitoxin of diphtheria is powerless to overcome the toxins of diseased germs, other than that of diphtheria, has led Buchner to promulgate the theory that antitoxins are derived from the injected toxins; in other words, that the latter have been converted into non-poisonous, protective substances by the cells of the animal body. The antitoxins are, in this sense, simply bacterial products modified by the tissues of the body into which they are injected, and made capable of counteracting the poisons from which they are derived. Their wonderful action is on these grounds made simple by Buchner, who looks upon it as only a modification of the methods of vaccination in vogue for many years past, and therefore not an essentially new method. When the antitoxin acts after the disease has broken out, as in human diphtheria, he believes that it simply immunizes, protects or vaccinates those regions or cell territories of the body not yet affected by the poison, and therefore causes the disease to halt. The theory at first suggested by Behring would assume a neutralization of the poison already in possession of the field.

Whether the antitoxins are toxins transformed by the cell activity of the body, or whether they are weapons created anew by this same cell activity under the irritation caused by the presence of bacteria and their toxins, as is assumed by the French school, we must leave undecided. As regards their *modus operandi* it may be safely stated that the weight of evidence is against the theory of direct action of antitoxin upon toxin, and in favor of the theory that the antitoxin acts only by stimulating the powers of resistance of the body cells.

Another question which here presents itself is the nature of the immunity conferred by the antitoxins. When an animal is inoculated with attenuated or sterilized cultures of certain specific disease germs, it passes through a mild attack of the disease. There are fever and other symptoms of illness noticeable for a time. A second and larger dose of the

same culture may lead to the same transitory symptoms. Finally, after a series of such inoculations or vaccinations, the animal is able to withstand many times the fatal dose, and thereafter that animal is insusceptible. But when the serum is injected this is not the case. The animal itself does not pass through a mild disease by which it is able of its own accord to resist the toxin, but the injected serum protects it while the animal apparently remains passive. For instance, when antitoxic serum is injected into the still healthy children of a family where disease has broken out, these children do not contract the disease for some six weeks, because the serum protects them. But after that time a new injection has to be made in order to prevent infection. If those children had passed through the diphtheria disease itself they would have become sufficiently immunized to protect themselves subsequently, and in their blood antitoxin would be present. That is the difference between the active immunity of the disease itself and the passive immunity conferred by the antitoxin.

Now as to the application of antitoxin. This is a professional matter, and it is something into which I do not care to enter. I shall simply make a few statements in regard to its use.

There are two uses to which it can be put. The most important, of course, is the curative. The great difficulty in medicine is to cure disease after it has broken out. You can prevent diseases, but the cure requires a great deal more power or influence from outside through medicines or in some other way. It illustrates once more the old adage than an ounce of prevention is worth a pound of cure. So it is with the serum. The serum injected on the first day of the disease will more speedily break it up than if injected on the third or fourth day. Then it has only a partial effect, and larger doses must be injected in order to stop the disease from proving fatal or from continuing in its ravages.

Its action is not peculiar to itself. It is nothing more than nature's remedy manufactured under artificial compulsion by the horse, and transferred by the ingenuity of man to the body of the feeble child. The serum simply augments the forces of resistance, without adding any that are unknown to or radically different from those in the human body. The curative action must, therefore, proceed along the very paths followed by the human body in a spontaneous recovery. No unusual symptoms, no miraculous change, should be looked for, nothing beyond a quickening or acceleration of the favorable course. It is this fact which will make a true estimate of the remedy in many cases a difficult one.

Among the things which have been noticed by physicians is a more prompt removal of the membrane which forms in the throat, sometimes almost miraculously. It has also been noticed that where there

is a tendency, especially in very small children, for the disease to go into the larynx and produce a contraction of the aperture, causing suffocation and death, or where the tendency is to go down further and produce croup, or where there is a tendency for the membrane to go into the nose, a prompt injection of the serum stops this passage up or down, and saves a child which might have suffocated in a few days. It has been reported, especially from Europe, that that very severe operation which is known as tracheotomy, has become less necessary, on account of the check which the disease receives under the influence of the antitoxin treatment. This, of course, is a very great benefit, because the majority of the children that are tracheotomized die either from the enfeebled condition, or from septic results.

The remedy fails in very advanced cases, when the child is already run down by the saturation of the body with the diphtheria poison ; and it also fails in very severe septic cases—cases in which other bacteria, which get into the body through lesions produced in the throat, assist in the destructive work.

In order to determine whether certain cases of throat troubles are diphtheria or not, a method has been very thoroughly worked out of late and is now practiced in this city by the City Board of Health, and in other cities by other boards of health. It consists in rubbing a little sterilized swab of cotton at the end of a piece of wire over the membrane or diseased portions of the throat, and then rubbing this swab upon coagulated blood-serum in a tube. This tube is placed in a thermostat at the temperature of the body. The next morning a little of the growth is removed with a wire from the surface of the serum and examined under the microscope. If the diphtheria bacilli appear, notice is at once sent to the physician having charge of the case. Not infrequently, especially in adults, only certain other forms of bacteria are found, and the case is regarded as one of false diphtheria. In a city where prompt communication can be had between a central station where these cultures are examined and the physician, the latter can often wait before the administration of the antitoxin till he gets his message. This of course is impossible in the country. But the method subserves another important purpose. It tells the family, even though a few days later perhaps, that there is diphtheria in the house and that sanitary precautions should be carried out as fully as possible to prevent its spread.

As regards the naked-eye appearances of the diphtheria cultures, I have brought one with me from the laboratory, in order to show them to you. I also pass around an uninoculated tube for comparison. The little specks upon the serum are what we call colonies of diphtheria bacilli, bacilli that have been planted there and multiplied and formed a mass visible to the naked eye.

Antitoxin is furthermore applied as a preventive, and I think that it will be used very extensively in the future for this purpose. If a case of diphtheria occurs in a family where there are a large number of children who cannot be isolated, as, for instance, in the great tenement house district of New York City, the serum is at once injected, in small doses, however. Not more than one-fifth of the dose which is passing around would be used as a preventive or vaccinating dose, as we may call it. This, as I said a moment ago, will protect a child for fully six weeks. After that, if the disease has not been stamped out, another dose would be necessary.

The remedy has also been found very useful in large establishments containing children. This has been found especially true in the hospitals and charitable institutions of New York City. Immunization or vaccination with small doses where diphtheria has appeared, has shown excellent results. I would say that New York City has been the pioneer in this matter, both in the culture test for diphtheria and in the free distribution of the antitoxin. Large numbers of bottles are distributed to inspectors, who either hand it over to the physician, or make the injection themselves whenever necessary. The inspectors also make the culture test from the throat, or else induce the attending physician to make it, as the case may be.

In conclusion I would say that the study of toxins and antitoxins is only begun and that there is promise from the principles first discovered by Behring of valuable practical results in diseases other than diphtheria.

THE SEWERAGE SYSTEM OF INDIANAPOLIS.

By Charles Carroll Brown, Member of the Engineers' Club of St. Louis.

[Read before the Club, November 6, 1895.*]

In 1870 Moses Lane designed, for the city of Indianapolis, a system of sewers, which was intended to serve about three thousand acres, the extent of the city at that time, with some allowance for growth. Up to 1891, sewers had been constructed draining most of the streets on about one-half this area. Prior to 1891, 19.9 miles were built at a cost of $663,900.67, and during 1891 and 1892, 8.3 miles were built at a cost of $66,620.76, making the total length of sewers constructed, according to this plan, 27.4 miles, and the total cost $730,521.76.

The city had largely expanded by this time, and in 1891 it covered 9,610 acres, much of the new area lying in a direction different from the direction of growth in 1870. A new system was therefore necessary to serve the new territory and to relieve some overcharged sewers in the district covered by the old system. Some of these old sewers were overcharged at their lower ends, though much too large at the upper ends, because they were made of uniform diameters throughout, those diameters apparently approximating the mean diameters for properly designed sewers on the lines. These sewers serve as examples of City Council engineering.

In 1891 the city was given a new charter by the provisions of which public improvements were put in the charge of a Board of Public Works appointed by the Mayor. Sewers are entirely under the control of the Board, although street improvements can be blocked by proper remonstrance, backed by the Common Council. One of the first steps taken by the Board of Public Works was toward plans for the additional sewers necessary. Preliminary topographical surveys were made, and Mr. Rudolph Hering was called in to make a general plan for the system and to advise as to the details of design and construction. Mr. Hering's report covers very completely the essential points and is readily obtainable.

I will now describe the work that has thus far been done, mentioning such details of construction as seem valuable, and giving the methods of letting contracts and collecting assessments, as they are in some particulars peculiar to Indiana and quite satisfactory in practical use. Reference should be made to the accompanying map and drawings.

There are four streams running through the city, viz., White River,

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Fall Creek, Pogue's Run and Pleasant Run, which, with the canal, divide the city into six drainage districts. See map, Fig. 1.

1. North of Fall Creek.
2. South of Fall Creek, formerly drained by the State Ditch.
3. Pogue's Run.
4. West of the Canal.
5. Pleasant Run.
6. West of White River.

These streams give economical methods of getting rid of storm water, so as to reduce to a minimum the size of the sewers necessary to carry the sewage of the new sections of the city round the old section to the river below the city. The plan in general provides for

I. Intercepting sewers.
II. Main sewers.
III. Local sewers.

I. An intercepting sewer is located on one or both banks of each stream in the first four districts, so as to receive all of the ordinary flow from the main sewers and a considerable part of the first storm water, and carry it down to the main intercepter, which carries the collected sewage of the first four districts mentioned to the river near the southern city limits. When the river becomes objectionable at the present outlet, the sewer can be extended farther down, or, if there is complaint from districts below the city, the sewage can be pumped into a plant for its treatment at the present mouth of the sewer or farther south. The main intercepter is completed, the White River intercepter and the Pogue's Run intercepter are under contract, and papers have been prepared for the intercepter for the north-east district. For the north side of Fall Creek an intercepter is proposed, which will cross the creek at Mississippi Street and discharge into the White River intercepter. The north-east intercepter will take the sewage from the proposed Manchester Street sewer and from the district along Fall Creek, on the south and east, and discharge it into the Fourteenth Street or State Ditch sewer. Thence it will flow into the White River intercepter, and thence into the main intercepter. Likewise the Pogue's Run intercepter discharges into the Washington Street sewer, the sewage flowing by way of Washington Street, Kentucky Avenue and Mississippi Street to the main intercepter.

The main sewers thus act at times as intercepters for a part of their course. On the other hand, the district west of the canal drains directly into the White River intercepter as its main sewer, so that the size of the sewer increases from 3 feet at its upper end to 6 feet 9 inches at Indiana Avenue. At this point an overflow is provided to take the storm water into Fall Creek, and the diameter of the sewer is reduced to

4 feet 6 inches, which is sufficient to carry the sewage. The diameter then increases gradually to 6 feet at Washington Street, as the storm water from the lower part of the district enters it. Another overflow is provided here, to discharge the storm water into White River, and the sewer is again reduced to 4 feet 6 inches and it so remains until the main intercepter is reached, as no additional storm water is permitted to enter.

Figs. 2 to 6 give some details of the junctions and overflow at Indiana Avenue as designed for the White River intercepter, and Fig. 7 gives the details of the connection of the Fourteenth Street sewer with the same.

II. As to main sewers.

(1) *The District north of Fall Creek* is just beginning to call for sewers. One sewer has been projected, but the Board of Public Works recently appointed has delayed its construction.

(2) *The District south of Fall Creek* has paid for the large State Ditch or Fourteenth Street sewer, the cost of which was $200,000 and for numerous branches thereto, and more will follow. There remain to be constructed the Manchester Street sewer and one discharging into Fall Creek near Central Avenue. Figs. 7 and 8 give some details of the Fourteenth Street sewer.

(3) *The Pogue's Run District.*—The Run flows near and through the principal business part of the city and the most densely populated part. There are therefore several sewers built and projected to discharge into this stream. It is not large enough to carry all the water coming to it, and there are also numerous obstructions in the way of bridge piers, foundations of buildings, arches, etc , which seriously interfere with the flow of water. On September 4th we had a rainfall of seven inches in ten hours, with about four inches of this in two hours, which brought the Run well out of its banks. This occurrence has renewed the discussion of plans for its improvement, and it is now proposed to straighten the stream and give it a cross-section such as is shown on Fig. 9. This work, complete, would cost about $600,000, and it is probable that it will be done in parts until the stream is found to be under control. Such floods as that of September 4th come but once in from ten to fifteen years. There were several interesting features in the construction of the Mississippi Street sewer, discharging into Pogue's Run at Merrill Street. Figs. 10 to 13 give drawings and photographs of some of these details.

(4) *The District west of the Canal.*—This district drains into the White River intercepter, now under contract and to cost $140,000. Several main sewers enter the intercepter, which is enlarged to provide for the storm water draining into it, and has overflows provided, as above described.

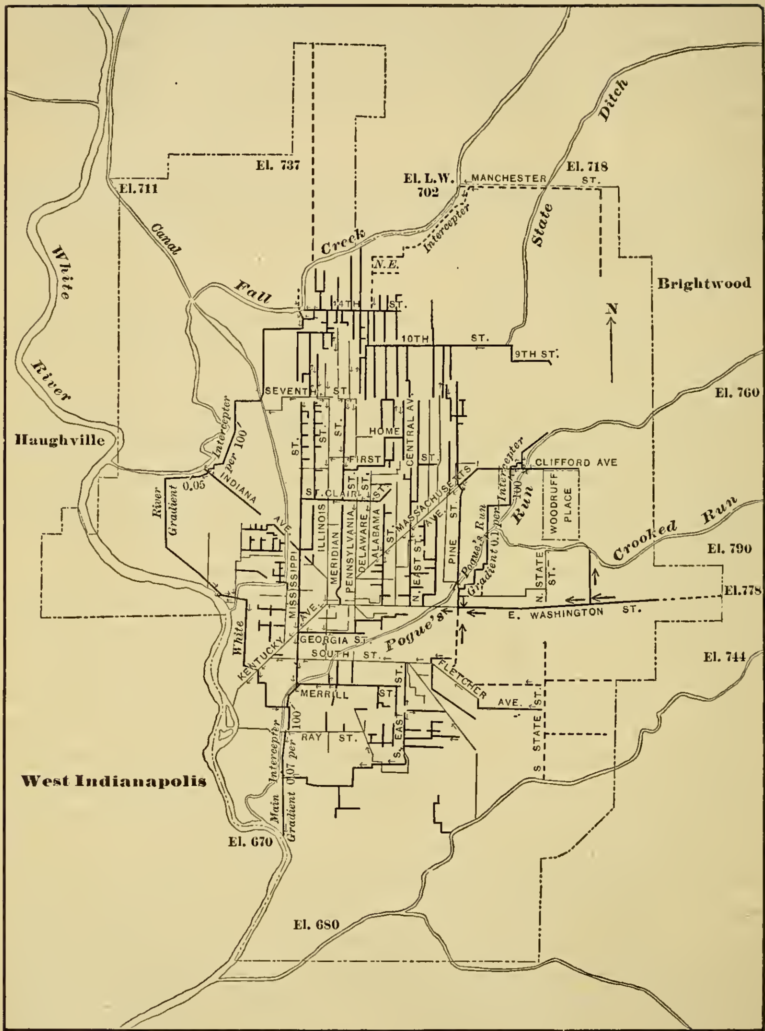


Fig. 1.—Map showing Sewers constructed in Indianapolis, Ind., January, 1896.

Sewers constructed prior to 1893.
" " during 1893, 1894 and 1895.
" (main) proposed.
City limits.

(5) *The Pleasant Run District* is independent of the others and will be treated independently. At present there is no call for sewers except for the removal of storm water, and there will probably not be a very loud call for some years, as this portion of the city is not now growing very rapidly. An independent intercepter discharging into the river near the mouth of the Run must be constructed for this district.

(6) *The District west of White River.*—Most of the area west of the river is in the city of West Indianapolis and the towns of Mount Jackson and Haughville, so that it will be necessary to absorb these corporations or to go into partnership with them in the sewer business. Most of the area within the city limits is low, as is that immediately north and south of it, and can be drained into the river only at low stage of water. It will probably be necessary to pump the sewage from this area. Nothing will be done with the sixth district until there are further developments in the way of annexation. The principal street—Washington Street—is paved with brick, and an ample drain for carrying off the water from the street was constructed as a part of the improvement. Some of the property owners resisted the payment of their assessments for the construction of the street because they considered the drain not properly a part of a street-paving plan. The case was carried to the Supreme Court of the State, and the decisions have all been in favor of the method of construction and assessment followed.

Fig. 1 is a map of the sewers constructed and now under contract. The fine lines show the lines of the old system and the heavy lines those of the new. The projected sewers likely to be built at an early day are shown by dotted lines.

7.8 miles of sewers were built in 1893 at a cost of .	$148,887 60
20.0 miles were built in 1894 at a cost of . . .	633,330 69
20 miles were constructed or put under contract in 1895 at a cost of about	400,000 00
Total of the last three years, 47.8 miles, costing	$1,182,218 29

making the total of the old and new systems about 75 miles, costing about $2,000,000.

The intercepters are named on the map and the main sewers will be easy to recognize in most cases.

The following are the principal main lines:

Of the old system, Kentucky Avenue and Washington Street to Pogue's Run, with its branches, South Street and Ray Street. The Kentucky Avenue sewer is intercepted by the new Main Intercepter, and also by the new Mississippi Street sewer.

Of the new system, the Mississippi Street sewer from Pogue's Run to St. Clair Street, thence east to Meridian, north to First, east to Alabama, north to Home, east to Central and north to Seventh; (This

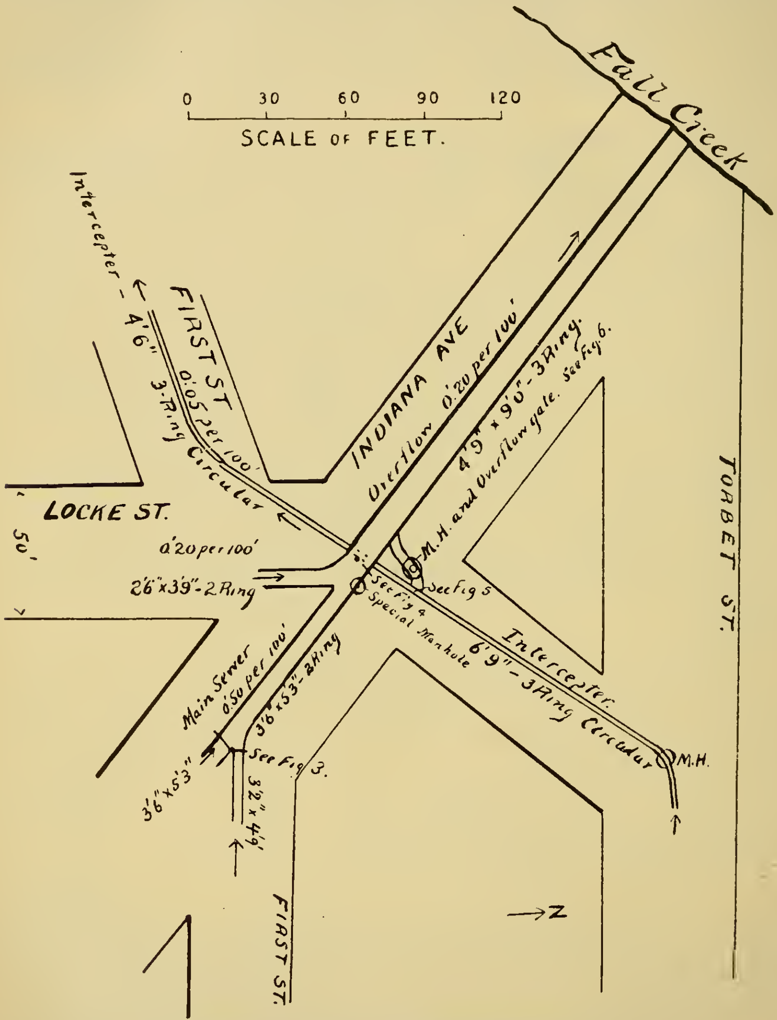


FIG. 2.—WHITE RIVER INTERCEPTER.

Indiana Avenue Junction and Overflow.

sewer cuts the old Kentucky Avenue sewer and turns the sewage down Mississippi Street, leaving the lower portion to act as an overflow for storm water. See Figs. 10 to 13 for details of the construction of this junction. It also cuts off the upper ends of the Illinois, Pennsylvania

and Delaware Streets sewers, and has several other branches, as shown); East Street, intercepting the old Massachusetts Avenue sewer, and having branches as shown; Pine Street and Clifford Avenue; East Washington Street; also the sewer marked Hill Street on the map which, for a short distance, takes the place of an old sewer of insufficient depth. All of these are in the Pogue's Run district. All of the principal sewers in this district are now constructed except one in and near Crooked Run and one for the district west of State Avenue and north of Fletcher Avenue. The State Ditch sewer, shown on 14th, Delaware, 10th and 9th Streets, in the district south of Fall Creek. The Manchester Street sewer, shown on the map as projected, would be constructed largely to relieve this sewer of storm water from a large district

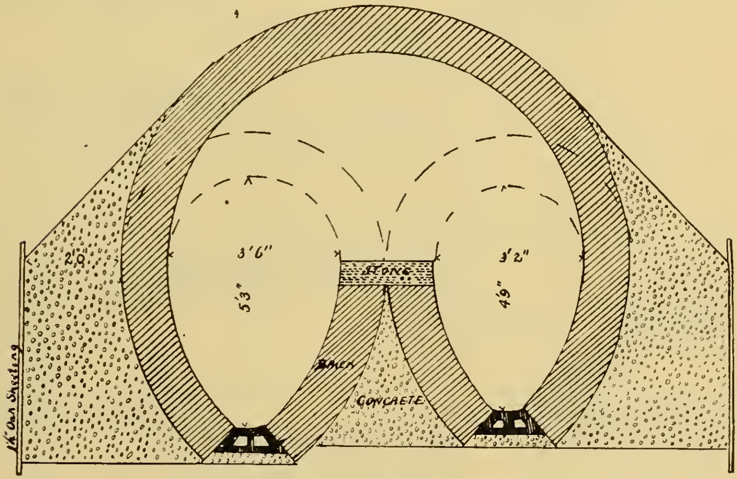


Fig. 3.—White River Intercepter.
First Street Junction. Scale, 1 inch = 4 feet.

outside the city limits. The number of main sewers, in the sense of the term thus far used, which remain to be constructed in the present settled portions of the city is therefore quite small, thanks to the activity of the last three years. Besides the projected main sewers, a number of local sewers will be constructed in the next few years, but they will all be small and inexpensive. In the resolutions for their construction some of them will be styled main sewers, as later explained.

Figs. 2 to 6 give details of the intersections and junctions at Indiana Avenue and Fall Creek and the overflow for the White River intercepter. Fig. 2 gives the plan of the sewers at this junction. The Indiana Avenue sewer, 3 feet 6 inches by 5 feet 3 inches, is the principal main sewer. It is joined by the First Street sewer, 3 feet 2 inches

by 4 feet 9 inches, without increase in its size on account of the increase in gradient at this point. When joined by the Locke Street sewer it changes to 5 feet 3 inches circular for fifty feet or so until the intercepter is reached. The intercepter is on a lower level, as shown, and the sewage from the Indiana Avenue sewer enters in by a 12-inch pipe, the storm water passing over the top of the intercepter into the common overflow for the Indiana Avenue sewer and the intercepter. The overflow for the intercepter begins just above (north of) the Indiana Avenue sewer intersection and takes the storm water from it. Fig. 3 shows a cross-section of the junction of the Indiana Avenue and First Street sewers, taken on a broken line at right angles to both lines. This is the standard form for such junctions.

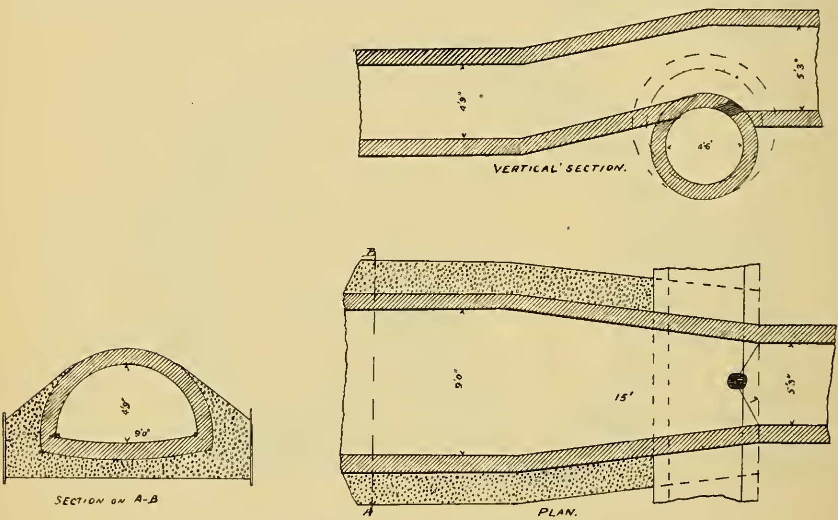


Fig. 4.—White River Intercepter.
Overflow of Indiana Avenue Sewer. Scale, $\frac{1}{12}$ inch = 1 foot.

Fig. 4 shows the connection of the Indiana Avenue sewer with the intercepter. The Indiana Avenue sewer is 5 feet 3 inches circular, as shown on Fig. 4 at the right. The bottom of the sewer is about 12 inches below the outside top of the intercepter. Just at the point of contact a 12-inch iron pipe is inserted in the intercepter to receive the ordinary flow of sewage. Storm water, when in sufficient quantity, overflows the dam formed by the projection of the intercepter into the sewer and flows through the overflow sewer to the creek. The height of the overflow sewer is fixed by the overflow from the intercepter, shown in Fig. 5, and the width is made sufficient to take the water from the Indiana Avenue and the intercepter overflows with as little head of back

water as possible. The form of the overflow is shown in the "Section on A–B" in Fig 5. Fig. 5 shows the intercepter overflow. The intercepter is here 6 feet in diameter. An opening is made in the side, 6

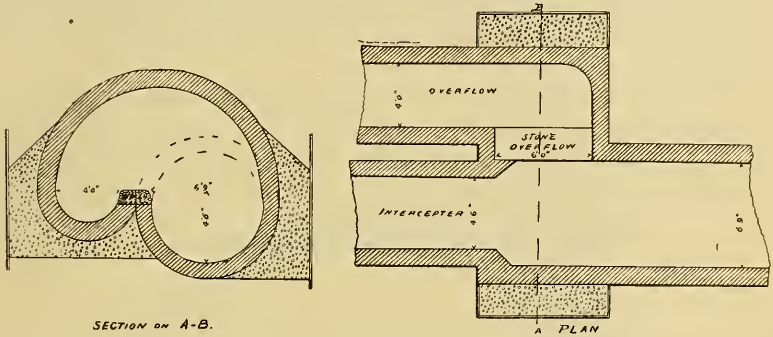


FIG. 5.—WHITE RIVER INTERCEPTER.
Overflow at Indiana Avenue. Scale, $\frac{1}{12}$ inch = 1 foot.

feet long and 4 feet 6 inches above the bottom, over which the storm water runs into the connection with the main overflow sewer 4-feet in diameter. In this 4-foot section is put a manhole and a back water gate to prevent water from the creek from running back into the intercepter when the creek is high and the intercepter is low. The intercepter reduces to a 4-foot 6-inch circular sewer immediately below the overflow. The gate referred to is shown in Fig. 6. Before water rose to the top of

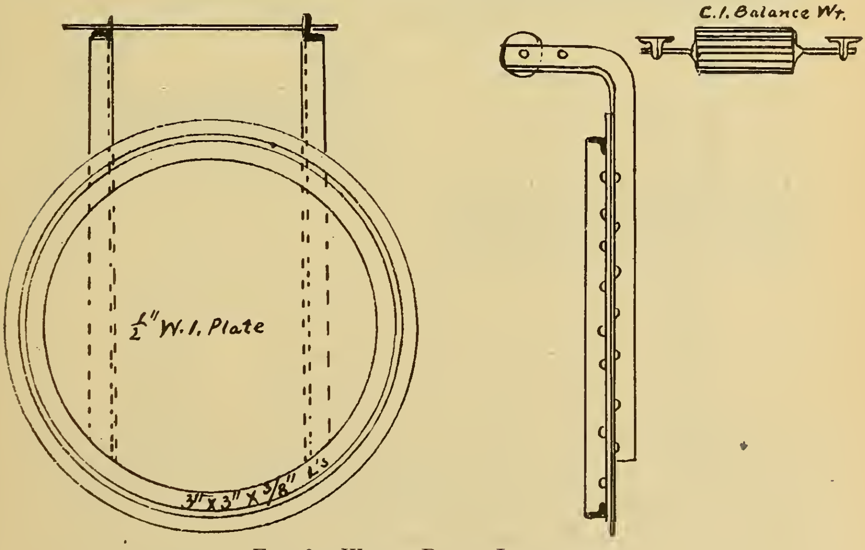


FIG. 6.—WHITE RIVER INTERCEPTER.
Overflow Gate. Scale, ½ inch = 1 foot.

this gate it would run into the intercepter through the 12-inch pipe in the Indiana Avenue overflow, shown in Fig. 4, but the pipe is small, and the back water from the Washington Street overflow into White River would probably reach to Indiana Avenue when Fall Creek was at this height, so no way of closing the pipe is considered necessary and none is provided.

Fig. 7 shows the connection of the Fourteenth Street or State Ditch sewer with the intercepter. The plan shows the curved form of the bed of the connection with the intercepter, which runs gradually down from the bottom of the main sewer to a point 36 inches below. The section

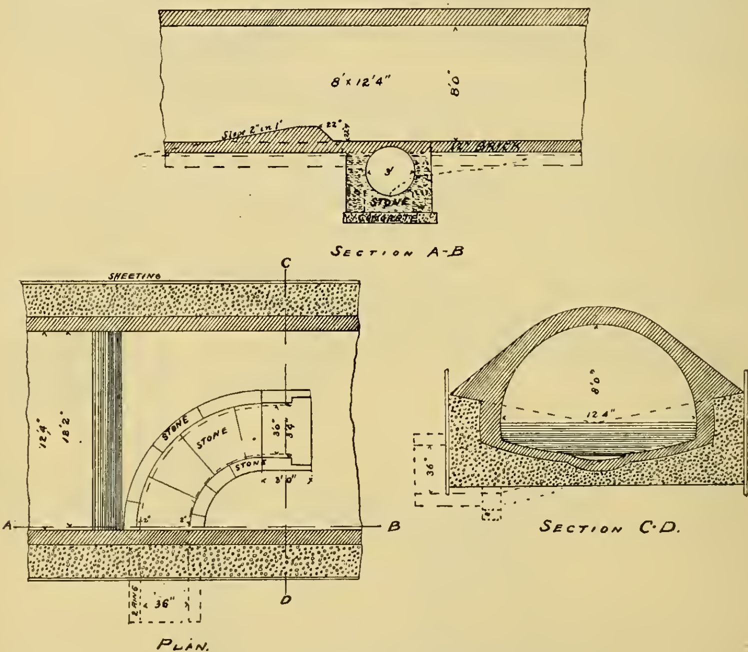


FIG. 7.—FOURTEENTH STREET SEWER.
Connection with White River Intercepter.

C–D and the section A–B make the construction clear. The dam below this intercepter connection will be 12 inches high. With the exception of the dam, the construction was made when the Fourteenth Street sewer was built, some three years ago, and was filled up with stone and a covering of cement. When the intercepter now under construction is brought to this point, the stone will be taken out and the dam built. Fig. 8 gives a section of the lower end of the sewer, with location and method of junction with manhole.

Fig. 9 shows a common form of the proposed improved cross-section of Pogue's Run. The bed of the run is to be depressed from three to five feet; walls are to be built for banks, where not already in proper place; the clear width is to be made uniform, 41, 40, 38 or 36 feet, as

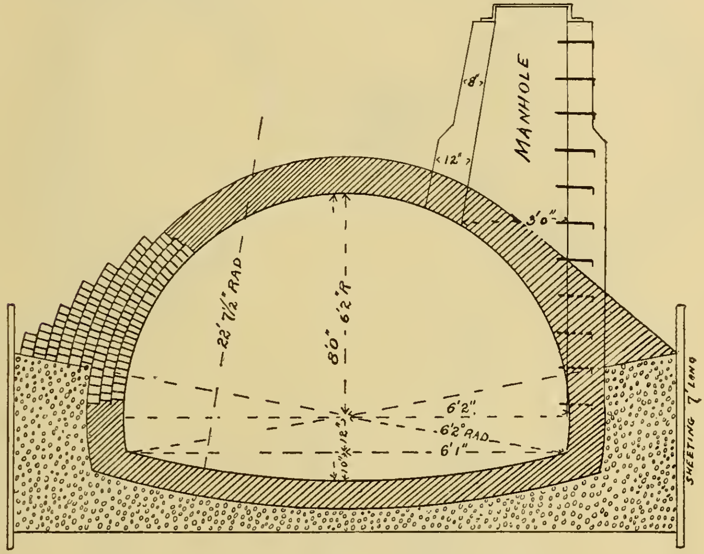


FIG. 8.—FOURTEENTH STREET SEWER.
Section of 8′ 0″ x 12′ 4″ Sewer. Scale, $\frac{3}{16}$ inch = 1 foot.

required; the bed is to be given a slope towards the center and is to be paved; and, as shown, a stone channel, large enough to carry the low water flow in the stream, is to be constructed in the center. Bridges and such buildings and railroad tracks as may be constructed over the

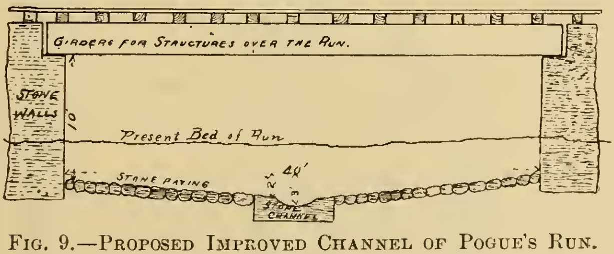


FIG. 9.—PROPOSED IMPROVED CHANNEL OF POGUE'S RUN.
Scale, 1 inch = 16 feet.

run will be supported on girders such as are shown. At present the depth of the run is insufficient in some places, and the channel is crooked and uneven in width, so that eddies form and the bed fills up in places at each flood, forming obstructions for the next. There are also numer-

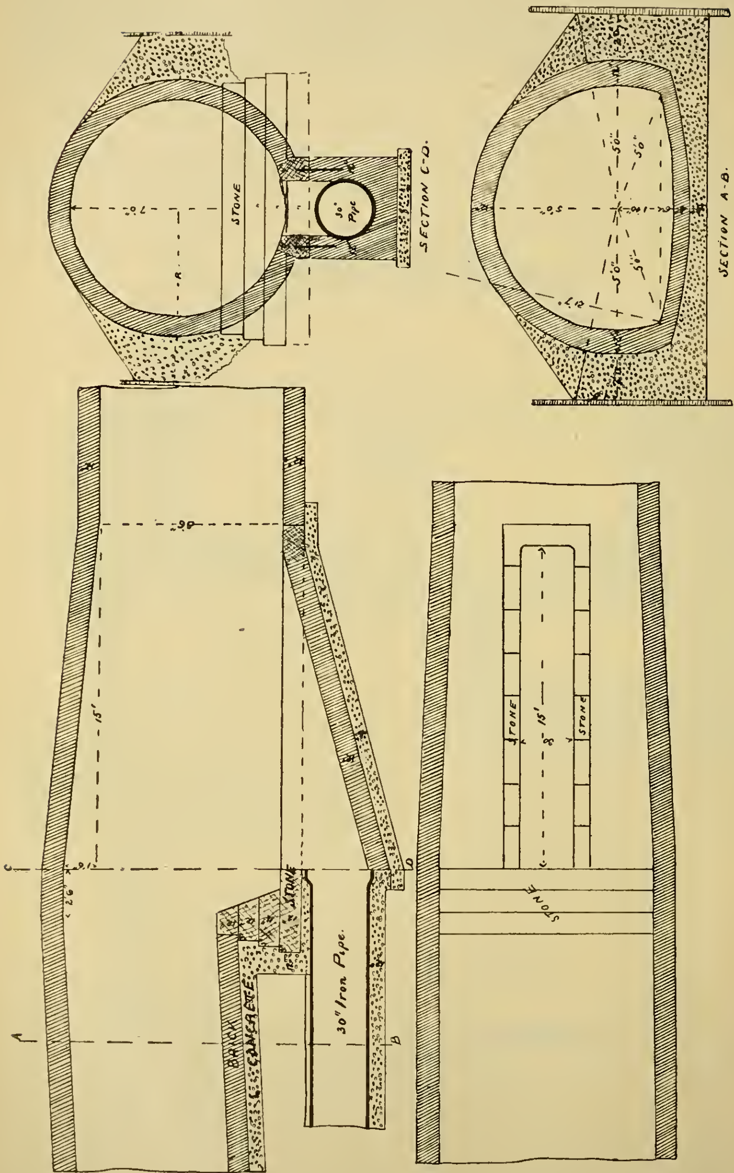


FIG. 10.—MISSISSIPPI STREET SEWER.
Overflow at Pogue's Run. Scale, $\frac{3}{16}$ inch = 1 foot.

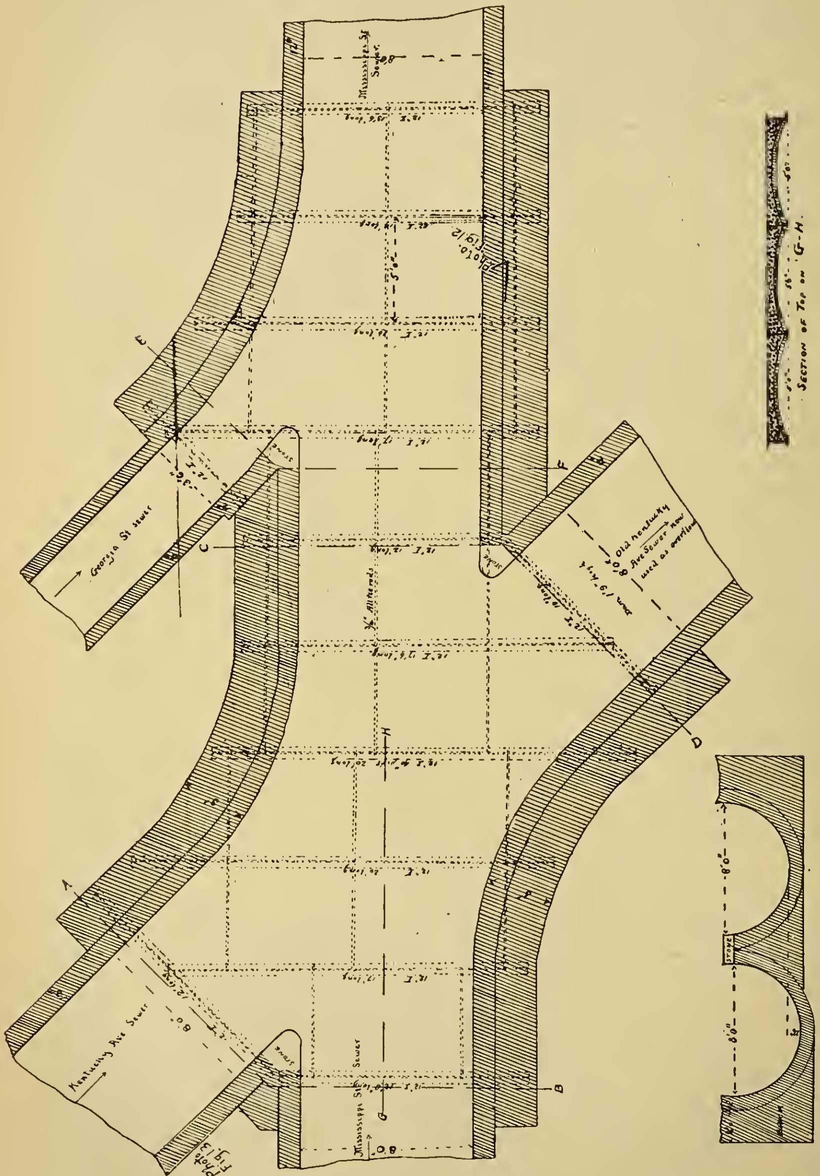
ous obstructions from walls out of line, contracting the width of the channel or interfering with the straight flow of water, and from piers of arches or supporting buildings, all of which serve to make floods in the stream dangerous to life and destructive of property.

Fig. 10 shows the connection of the Mississippi Street main sewer with the main intercepter, and the overflow into Pogue's Run. The drawings show the construction quite clearly. In this case the dam is higher than usual, rather to keep the water of Pogue's Run from going back into the sewer than to turn the sewage into the intercepter. With a channel in the bottom 15 feet long and deepening, as shown on the plans, no dam is necessary to turn the sewage into the intercepter, as all the sewage gets into the sinking channel within a few feet of its beginning. Such a channel has also the effect of keeping the pipe connection with the intercepter clear of debris. Anything which lies across the sewer is floated out over the sunken channel and is out of the way, and anything else is straightened out in the channel and carried through the pipe without danger of stopping. When sufficient flood comes to overflow the dam, all floating matter is carried off into the run.

A comparison of the connections with the intercepter at Fourteenth Street, at Indiana Avenue, and at Mississippi Street, will show the three forms that have been used. Other connections are of about the same form as that at Indiana Avenue. The experience with these latter connections is that they are easily obstructed by sticks, which collect smaller refuse until the sewage overflows the dam and runs into the stream near by. This calls attention to the stoppage and calls for its removal. The Mississippi Street connection, on the other hand, keeps itself clean and has never been seen with any refuse lodged about it. The Fourteenth Street connection has not yet been put into use, but it may be presumed that it will be liable to similar stoppages to the first ones mentioned, though not so frequently, on account of the size of the connecting pipe.

Figs. 10 and 11 show also the intersection of the new Mississippi Street sewer with the old Kentucky Avenue sewer. Both are 8 feet in diameter above the junction, and the Mississippi Street sewer is 8 feet and 6 inches below the junction. The smaller Georgia Street sewer comes in on one side. The principal feature of the design is the roof. Instead of the customary arch, which would be of unusual dimensions and require a large amount of material to make it sufficiently strong, it is made of 12-inch I-beams, weighing 40 pounds to the foot, set 5 feet apart, with brick arches between, the whole being covered with 12 inches of concrete. The arches are kept from spreading by $\frac{3}{4}$-inch tie rods, as shown on plan. It was the intention to protect the iron with tile, where not covered by the brickwork of the arches, in a manner similar to that used in building construction, but the roof was finally built as shown

Scale, 1 inch = 9 feet.



Scale, 1 inch = 12 feet.

FIG. 11.—MISSISSIPPI STREET SEWER. Scale, 1 inch = 9 feet.
Intersection with Kentucky Avenue Sewer.

without this covering, the beams being thoroughly covered with three coats of asphalt paint put on hot before and after lowering into the trench and after being put in place. A special manhole is built just outside the area shown in the drawing to permit of inspection and measurements. The location of the photographs, Figs. 12 and 13, are shown on Fig. 11.

Figs. 12 and 13 were taken just before the roof was put on. They show the beams across the branch sewers, which carry the roof beams at

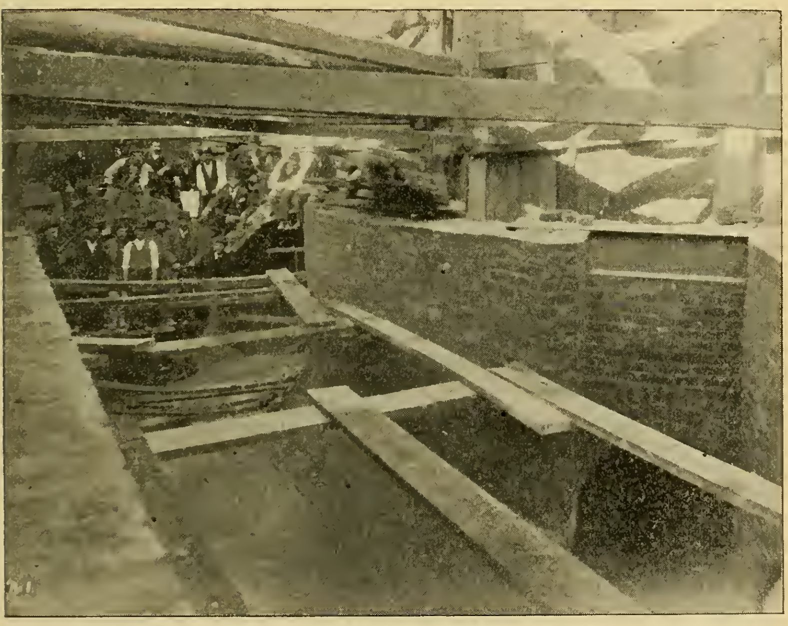


FIG. 12.—MISSISSIPPI STREET SEWER.

Intersection with Kentucky Avenue Sewer.

those points; and Fig. 13 shows one of the main roof beams in process of setting.

I quote the following from Mr. E. Hill, the inspector in charge of the work, regarding the experience with water during the construction. Both the Georgia Street and Kentucky Avenue sewers were in use, and the sewage must be taken care of during construction of the junction.

"The upper section of the Mississippi Street sewer, having been given a temporary connection with the Kentucky Avenue sewer, the top of the Georgia Street sewer, which crossed the main ditch, was taken off and a bulkhead built in it at the east side of Mississippi Street.

Another was built in it on the west side of Illinois Street (the next street east and above), turning all water from Illinois and east Georgia Streets down the Illinois Street sewer, leaving only the water that accumulated between Illinois and Mississippi Streets to be taken care of, which was kept in the sewer until the invert was completed. The part of the sewer across the ditch was then taken out and the junction constructed on a curve, as shown on the plan. When the work had progressed far enough past the junction, the bulkheads were taken out and the water from Georgia Street sewer was allowed to pass down the new sewer. In

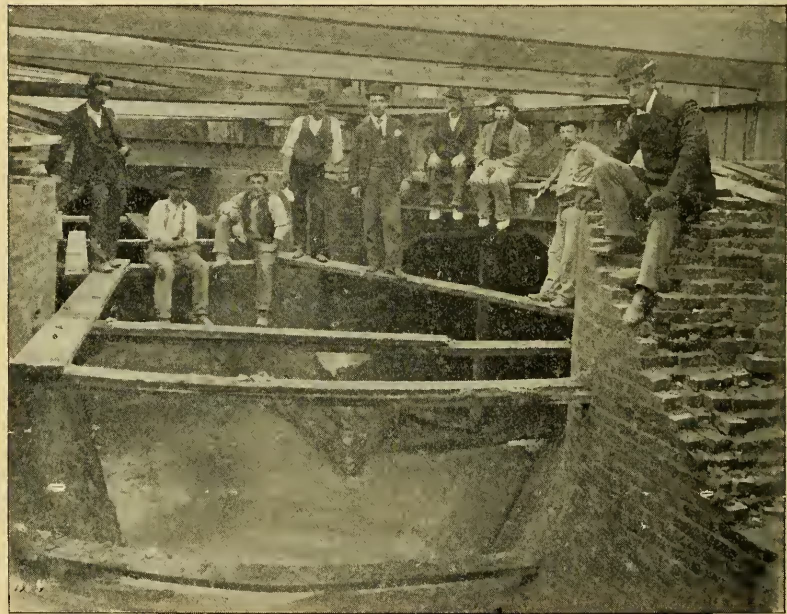


Fig. 13.—Mississippi Street Sewer.
Intersection with Kentucky Avenue Sewer.

meantime the work of tearing off the top of the old Kentucky Avenue sewer, and the placing of a wrought-iron pipe between bulkheads, had been completed. The pipe was 30 inches in diameter and 42 feet long, made in three sections to facilitate handling. Twenty-six feet of it had been an old boiler and 16 feet was new, made for the purpose, of ¼ inch plate. The whole was bolted together. The pipe was firmly bedded in the bulkheads. To prevent removal by the water in case of flood, the bulkhead on the east side was 6 feet thick and thoroughly cemented together. It was at this stage of the work that we were visited by a heavy

storm that had been threatening for three days. The invert of the Mississippi Street sewer was in just past the Georgia Street sewer and up to the Kentucky Avenue sewer on the west side, and the side walls were about half way up when the storm came. The upper part of the Mississippi Street sewer had been constructed, but was not yet in use. However, some water did reach it. There was a temporary bulkhead in it at its lower end (the upper end of the excavation for the junction), which burst, and the accumulated water washed out a part of the sheeting across the end. Georgia Street sewer ran full at Illinois Street, but the 30 inch pipe stood its ground and carried off all the water coming down the Kentucky Avenue sewer. I account for this by the water backing up, and the capacity of the sewer being such as to hold it until the flood subsided. One and seven-tenths inches of rain fell in fifteen hours, and one inch of it fell in one hour. Outside of washing into the sewer a large quantity of sand, the damage was slight. The work was delayed a few hours, and the first thing done was to repair the broken bulkhead and put in another one at Mississippi and Washington Streets, and make a connection with the Washington Street sewer to turn the water from the upper section of the Mississippi Street sewer west, until the work was completed. The work of completing the inverts of the Mississippi Street and Kentucky Avenue sewers was then proceeded with and was no mean task. The angles and curves were laid off according to plan, and in order to insure true curves in the brickwork, I had curves made out of wood and placed in proper position for the masons' guidance. You will readily see that the whole of the invert was simply a series of groined arches upside down and strengthened by placing them in solid brickwork, as the outside of the side walls was carried down vertically to the bottom of the invert, the walls being 3 feet wide at the top. A dam was constructed on the west side of Mississippi Street, in the lower section of the Kentucky Avenue sewer, 1 foot 9 inches high. This will make a total height above the bottom of the Mississippi Street sewer of 2 feet 4 inches, so that the water must get above this dam before it can go down the Kentucky Avenue sewer to the river, which sewer was the original outlet for nearly all the sewage of the city."

The method of carrying through an improvement and collecting the payment for it is as follows:

The Board of Public Works orders the City Engineer to prepare plans for the sewer desired. This order may be given with or without petition of property owners interested or to be affected.

The City Engineer prepares the plans and specifications, including therein full directions as to manner of doing the work and a statement of the entire amount of work to be done, with full detail drawings showing location of sewer and all appurtenances and connections and specifications of kind and quality of materials required. The total length of

the sewer to be paid for is specifically stated, and the line is described. All branches or connections not given in the description of the line are appurtenances and not considered in measuring up the length of sewer constructed.

Should the sewer be a local sewer, intended to serve only the property abutting on it, a resolution is prepared, stating that the Board considers it necessary to construct a local sewer on the described route under the accompanying plans and specifications, to be paid for by the abutting property. Should the sewer be a "main" sewer, intended to serve not only the abutting property but also as an outlet for branch sewers, the City Engineer estimates the cost of the sewer as designed and the cost of a sufficient local sewer on the same line, and thus determines the percentage of the total cost which is properly chargeable to the abutting property. This percentage is stated in the resolution, which differs from the local sewer resolution also in describing the district over which the remainder of the assessment is to be distributed, and containing a map of the district. In the resolution any liability of the city for any part of the cost other than as any other property owner, is specifically disclaimed, and the areas of streets and alleys are not included in the total area of the district to be assessed. This resolution is passed as a declaratory resolution, and a day for hearing remonstrances from persons interested in or affected thereby is set and advertised once each week for two weeks. On the date set the Board takes final action, confirming, modifying or rescinding the original resolution, and such action is final and conclusive on all persons.

If the resolution is confirmed or modified, notice of a day for receiving bids for constructing the work according to the final form of the resolution is published once each week for two weeks, such day being at any time not earlier than ten days after the first publication of advertisement for bids. On the day set, the bids are received and opened and the contract may be awarded. The custom has been to award the contract to the lowest bidder and to reject all bids if the lowest bidder were not a satisfactory person. Sometimes, when the difference between the lowest bidder and the next was not too great, the contract has been awarded to the next lowest. The Board reserves the right to reject any or all bids. In the case of street improvements, the lowest bid is frequently rejected if the material proposed to be used is not satisfactory, but this is not necessary in the case of sewers, as all bidders will use practically the same kind and quality of material. (It will be noted that it is not possible for a sewer to be stopped by remonstrance if the Board deems it necessary to pass the resolution.) The contractor files with his bid a certified check of amount stated in the advertisement, which is returned to him if his bid is not accepted, or, if his bid is accepted, when he has filed his bond of 50 per cent. of the cost of the work, for construction and maintenance

of the work according to specifications. The bond covers the construction of the sewer and its maintenance in good condition and repair for a period of three years from the date of its completion.

When the bond is accepted and the contract signed by the Board and by the contractor, the contractor begins work within the time limit set by the contract and completes it within the time limit set, under penalty of $50 a day for delay, unless the date of completion is extended by resolution of the Board. The bid states the price per lineal foot at which the sewer will be constructed, and is practically obtained by the contractor by computing the entire cost of the sewer with all its appurtenances, and dividing this cost by the length of the sewer proper. given in the specifications. According to the strict letter of the charter provision, the assessment roll would be made up with this contract price and length, but, practically, the sewer may differ somewhat in length from the specified length, and so the completion of the assessment rolls is delayed until the sewer is completed, when the City Engineer measures its length and reports to the Board of Public Works the total cost of the sewer, which is this length, multiplied by the contract price per lineal foot, less deductions for appurtenances or connections or other work not constructed, and plus such extra work as has been agreed upon by the Board and done by the contractor. There is no definite provision in the charter for these deductions and additions, but there are numerous decisions by the Courts justifying them, and others which would show that, even if they do not come under the decisions mentioned, the assessments against property would only be successfully attacked so far as the few cents due to the extras are concerned.

The assessment roll is then prepared by the assessment bureau. In the case of a local sewer, the assessment is made by dividing the total cost by the area of the abutting lots in square feet, with special provisions limiting the depth to 200 feet in case of unplatted ground not already assessed for sewer on one side, or to 50 feet in case such ground already has a sewer on one side intersecting the side on the new sewer. The assessment against each piece of property is then determined by multiplying the area of the lot by the cost per square foot. In the case of a main sewer, the amount of local assessment is determined from the total cost and the percentage thereof to be assessed locally, stated in the resolution, and the local assessment on each piece of abutting property is obtained as above. The total area of the property in the district, and the amount of the district assessment remaining after deduction of the local assessment, is then determined. The district assessment on each piece of property is then obtained in a similar manner. This is the total assessment on property not on the line of the sewer. Abutting property pays the sum of the local and district assessments. All of the large main sewers for the city, with the exception of

some outlying districts, have been paid or contracted for under this system, so that it would probably be unjust to modify the system now; but the system in use in the State outside of Indianapolis is better in one way, in that it permits the city to assume the payment of a portion of the cost of a sewer in case it is used for other than local sewerage, or is an outlet or intercepter of value to the city at large and of very little value to the abutting property along the lower end of its route. The city of Indianapolis, by the Common Council, did, however, pay a portion of the assessments against such property as that last described along the lower end of the main intercepter after the assessment had been made, and it was shown that the assessments operated to confiscate the property. There is, however, but the one instance of this.

When the assessment roll is completed, it is approved by the Board of Public Works and sent to the City Controller; he forwards a certified copy to the City Treasurer. The contractor must, within ten days, send to each property owner, notice of the approval of the assessment roll by the Board of Public Works. For thirty days after the approval of the roll, the owners of property assessed have the privilege of paying in cash or of electing to pay in ten annual instalments. In the latter case they must waive any objection as to legality or regularity of procedure. The deferred payments draw interest at the rate of 6 per cent., payable semi-annually. Coupon bonds, which are a direct lien upon the property assessed, are issued for these deferred payments. If the property owner fails to pay in thirty days, or at date of any semi-annual payment, the entire amount becomes due and can be collected by the contractor or by the holder of the bond, the city having no liability and no duty in the matter.

The fact that there are no partial estimates and no payments by the city, and that, therefore, the contractor must carry the work until thirty days after final completion and acceptance, operates to shut out small contractors and irresponsible persons from bidding on work of any magnitude, and as a consequence the character of contractors is above the average. The fact that each bond is for the sum due from a special piece of property, and is a special lien on it, makes the bonds of odd amounts. This, and the fact that one-tenth of the principal is payable each year, causes the bonds to be at a slight discount (2 to 4 per cent.), and increases the cost of work by so much. It would be possible for the city to issue the bonds for uniform amounts and times, and form a sinking fund from the annual payments to take them up when due; but so far that has not been done. Interest on the money invested in the contract also operates to increase the price bid. Notwithstanding all this, the work of the last two years has been done at an average price for good work considerably below that elsewhere with which I am acquainted.

Editors reprinting articles from this journal are requested to credit both the JOURNAL and the Society before which such articles were read.

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RECENT IMPROVEMENTS IN COAL-HANDLING MACHINERY.

By JOHN D. ISAACS, MEMBER OF THE TECHNICAL SOCIETY OF THE PACIFIC COAST.

[Read before the Society, February 7, 1896.*]

THE purpose of this paper is to describe certain improved apparatus for handling coal, recently constructed by the Maintenance of Way Department of the Southern Pacific Company, and applied to the receiving bunkers at Port Costa and Oakland Wharf, and to the distributing bunkers at San Luis Obispo, West Oakland and Rocklin.

Our conditions of operation require that most of our coal should be landed from ships into receiving bunkers, and transported thence by rail to the various points of consumption, at which points the coal must be placed upon the tenders of locomotives. The high cost of coal delivered at the wharf, the high rate of wages paid stevedores on this coast, and the importance of quick dispatch for colliers, indicate three directions in which it is desirable to economize :

(1) In diminishing as far as possible waste and breakage.

(2) In dispensing with manual labor in discharging and distributing.

(3) And much the most important, dispatch in discharging ships.

Of these, the need of the first and second is self-evident. As to

* Manuscript received April 1, 1896.—*Secretary, Ass'n of Eng. Socs.*

the third: It must be remembered that our colliers have an earning capacity in only one direction, that somewhat less than one-half their time is devoted to their actual business of coal transportation, and that therefore any means of diminishing their idle time is important.

An ideal system of landing coal from vessels would be some form of mechanical conveyor, delivering coal from the hull of a ship directly into the receiving bunker, digging its way into the coal until bottom is reached. This would be supplemented with a fore-and-aft conveyor, in the ship, bringing the coal to the main conveyor. Such systems are in use in the Eastern and Middle States for unloading barges.

But, on this coast, the many complications surrounding the problem seem to put this method almost beyond practical possibility. Some of the difficulties are: Variations in sizes of lumps, from dust to pieces a couple of feet in cubature; very wet coal, very dry coal, range of tides, variations in the draft of ships, and in the size and position of their hatches, the interference of ships' rigging, special construction of ships as to bulkheads, etc., etc.

Under these conditions there seems to be, at present writing, but one practical way of attacking the problem; that is, with a hoist or derrick, lifting a bucket which contains the coal. It is towards improving this method that our attention has been principally directed.

Although the ordinary tipper bucket is well known to you, it may not be out of place to remind you briefly of the principle of its construction and the mode of its operation, in order to bring out strongly the contrast between it and later forms now in use.

The tipper is constructed on the principle of an ordinary water bucket. It has a bail, and is so dimensioned that when it is empty the center of gravity of the bucket is below the trunions. When the bucket is filled the center of gravity is above the trunions and slightly to one side of the vertical through them.

The bucket is held in place by a catch. The tipper is provided with wheels. The mode of use is as follows: The empty bucket is dropped into the hold of the ship, disconnected from the hoisting line, pushed on planks to one side, filled by shoveling, trundled back, connected up and hoisted. It is swung over the bunker, and run up to the end of the derrick boom. At this point the catch is released by suitable mechanism, and the coal is thus dumped.

All this involves much manual labor and a high dump for the coal. To obviate these objections many varieties of dredger buckets have been devised. On this coast they are euphoniously called "grab buckets." They all work on the principle of the clam-shell dredger; *i. e.*, they dig their way toward the keel of the ship; the coal constantly tumbles into the inverted cone made in excavating, until, when the bottom floor is

reached, there remains only a portion of the coal, which has to be trimmed—that is, shoveled to the bucket.

The requirements for this kind of bucket are:

It must be simple in construction, having few parts and those easily replaced.

It must require no nice adjustment, and have no delicate mechanism.

It must not get out of order in working, and must be able to stand very rough usage.

Its cost must be moderate, and its repair account low.

It must be so geared as to "bite" lumps of coal in two when they are caught between the edges of the wings.

It must be so arranged as to bury itself well into the coal, so as to come up full.

It must work in any kind or condition of coal.

It must have a low dump; that is, it must be capable of delivering the coal on the pile with as little fall as may be desired.

It must be handled entirely by the derrick engineer, and be certain in action.

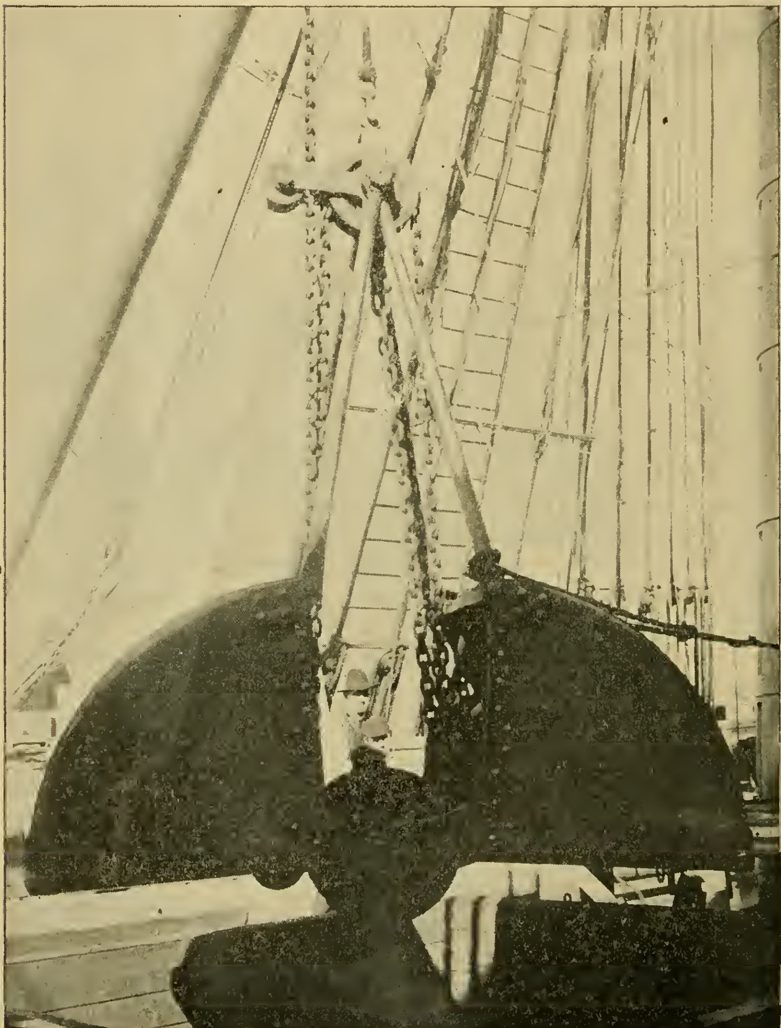
Of the various forms of buckets of the grab type brought to our notice, none seemed to us to fill all these desirable conditions. Those which conformed to the most essential—automatic action, low dump and applicability to various conditions of coal—proved to be very complicated. One of the best in operation is such a collection of gears, catches, springs, pawls, etc., that constant delay and expensive repairs seem necessarily to accompany its use.

The bucket is operated as follows: It is lowered into the hold, both lines being paid out together. When the bucket has nearly reached the coal, the running line is let go. The weight of the lower sheaves, hinges, etc., throws the bucket wide open by the time it reaches and rests upon the coal. The hanging line is now let go and the running line hauled in. The bucket buries itself in the coal up to the lower sheave shaft, and closes. Both lines are now run in together, but the lift is kept entirely on the runner. As soon as the bucket clears the hatch, swinging begins. The bucket just clears the top of the bunker, and no further hoisting takes place, but swinging continues up to the point of discharge. Here the hanging line is held and the runner released. The bucket opens promptly, and the coal is dumped. By this time a reverse motion towards the ship has begun.

Occasionally, in discharging, we come upon a layer of large lumps, which has much the appearance of a paving of coal, over which the bucket would slide without filling. A stevedore loosens this with a few blows of a pickaxe, while the bucket is up, after which there is no further difficulty.

S. PATENT

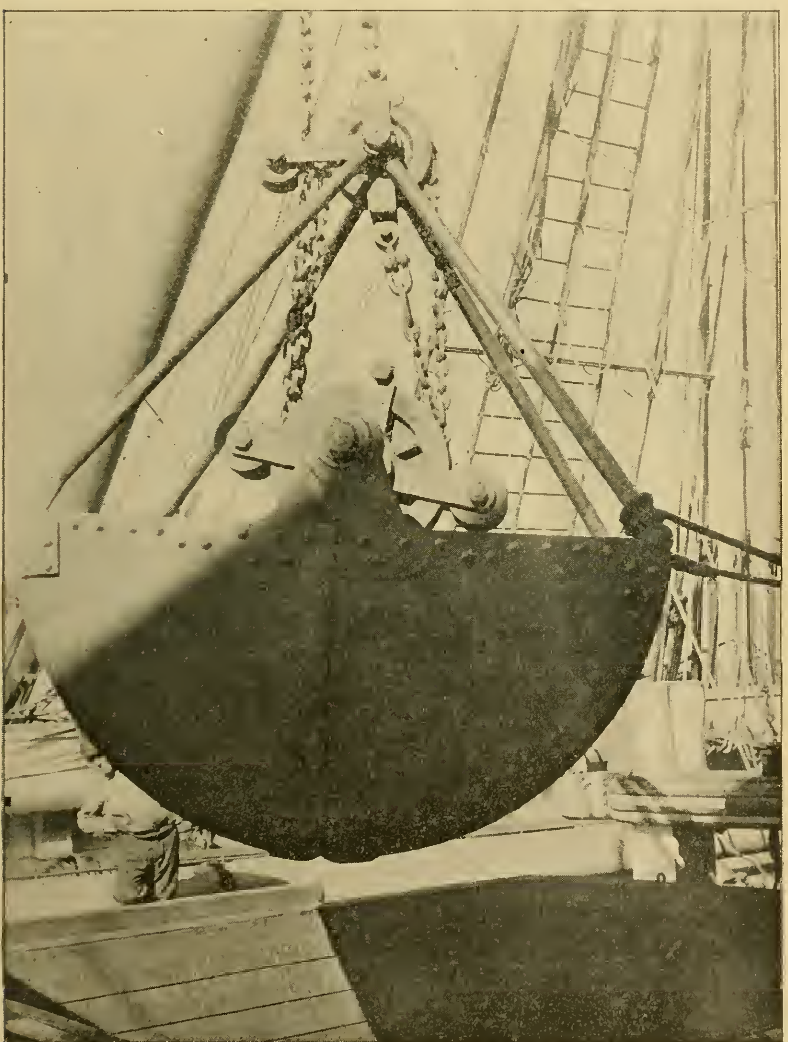
If the coal is very soft and friable, the bucket may be lowered to the coal pile before emptying, giving no appreciable fall to the coal. With ordinary coals this precaution is not necessary.



Grab Bucket Open.

It will be noticed that the center K of the pivot shaft is above the center with which the wings are struck. This gives a scooping motion to the bucket when closing, causing it to bury itself well into the coal.

The tipper bucket is limited in size and weight, by the fact that it must be trundled around in the ship. Buckets of this kind, used by us,

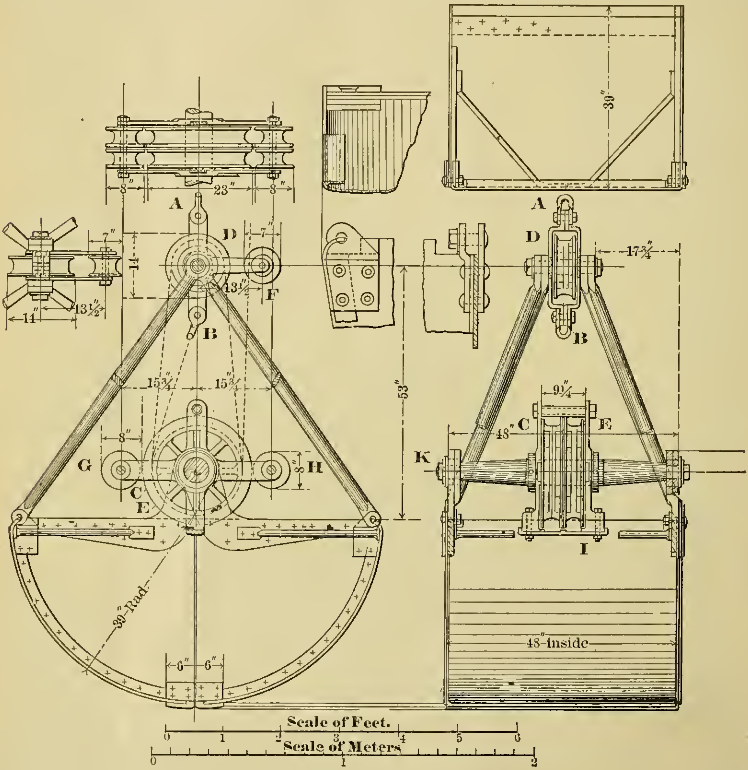


Grab Bucket Closed.

weigh 1,400 pounds each, and have a capacity of 700 pounds of coal, or a ratio of dead weight to useful load of two to one.

The grab bucket is limited in size only by the dimensions of the hatches and the capacity of the derrick. We have three sizes, with

capacities, level full, of 3,000, 3,800 and 5,000 pounds respectively. Of these, the second (3,800 pounds) seems to be about right for our conditions, and is now the only kind in use. Its weight is 3,775 pounds, giving a ratio of dead weight to useful load of one to one. The maximum speed of lift of each is about 400 feet per minute. The average fall of coal from the tipper bucket is 21 feet; from the grab bucket, 8 feet. The number of stevedores per hatch for tipper bucket,



Coal Bucket for Oakland Wharf.

Capacity, 64.4 cubic feet = about 3,800 lbs. Carbon Hill Coal at 59 lbs. per cubic foot level full. Weight of bucket, 3,775 lbs.

is six; for the grab bucket, one, until bottom is reached. Each kind of bucket requires a signal man at each hatch, whose duty it is to notify the engineer by bell code how to handle the bucket while it is in the hold. We usually keep a man at each hatch, when the coal has been excavated nearly to the bottom of the hold, to steer the bucket with a guy line, clear of lower deck beams, etc.

In view of these statements it requires no further particulars to

show a considerable gain in time in handling coal by the use of the grab bucket shown, and consequently greater dispatch in unloading our colliers.

Five of these grab buckets have been in almost constant use at Oakland Wharf since November, 1894. None of them have delayed work one moment by disarrangement, and, so far, they have no charges against them for repairs.

The derricks handling these buckets are of ordinary type, with double independent drums, friction brakes and the usual appliances for such machines. They have a reach of 32 feet, and are flexibly connected with a steam pipe between derrick tracks. The track gauge is 8 feet. The derricks are hooked down the track stringers when in use. The following are their principal dimensions:

Two cylinders 11 inches x 12 inches.

Two drums 36 inches diameter x 18 inches long, spirally grooved.

Tops of rail to center of boom sheaves, 18 feet 6 inches.

The engines are not reversible, as all lowering is done with brakes. The derricks may be disconnected and run to any point on bunker to suit ship hatches.

Steam is supplied from a suitable boiler at the end of the bunker through a continuous pipe laid between the derrick tracks.

The receiving bunker is in all respects, except that it has no inclined trestle approach, the same as the local distributing bunker which, with certain improved details applicable to both, will presently be described.

The next step is the transportation by rail from the receiving to the distributing bunker.

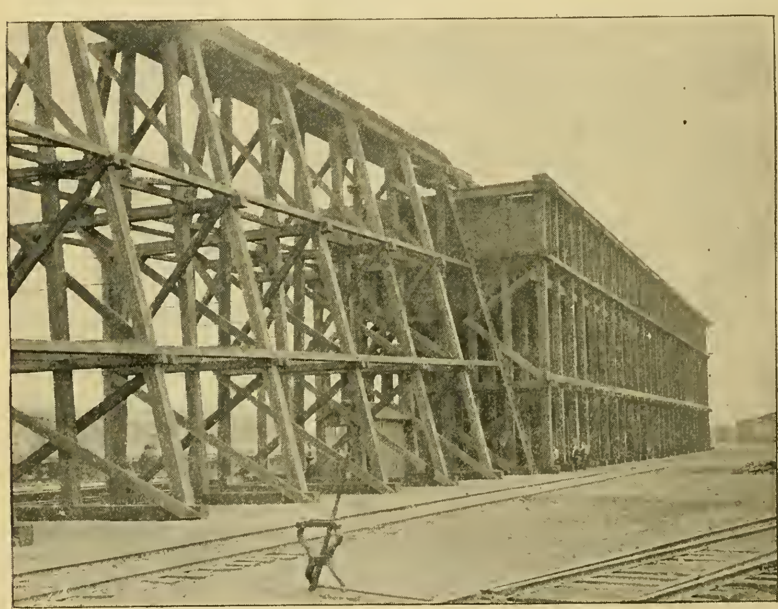
Coal cars are run on a track under one side of the receiving bunker. The cars are then filled, being moved slowly under the chutes to load them uniformly, and then hauled by locomotives to the distributing bunker.

The distributing bunker consists of a wooden framework, heavily built and well braced, as shown. At one end is an inclined trestle having a grade of 5 per cent. In order to enable the coaling tracks to pass under the bunker the first seven trestle bents next to the bunker are built unsymmetrically, but stability is maintained by horizontal bracing, which anchors the narrow bents to the bunker at one end and to the broader bents at the other. The bunkers have a capacity of 10 tons per foot run, level full. They contain an average of 1,266 feet board measure per foot run, and cost, by contract, about $36.60 per foot. The trestle approach contains an average of 266 feet board measure, and costs $6.60 per foot run. The track on top of bunker is 46 feet above the coaling track.

When the first of these bunkers—that at San Luis Obispo—was built, there was some discussion as to whether it was better to run the coaling tracks under the bunker or outside. The plan was adopted because it takes up the least yard room, and because (as it is desirable to be able to empty the bunker from some one track) this form gives the greatest capacity for a given height and width.

On the coaling track there is a track scale just before the bunker is reached.

On arrival of the loaded cars in the yard, a switch engine is coupled to them, taking from two to four at a time. The engine

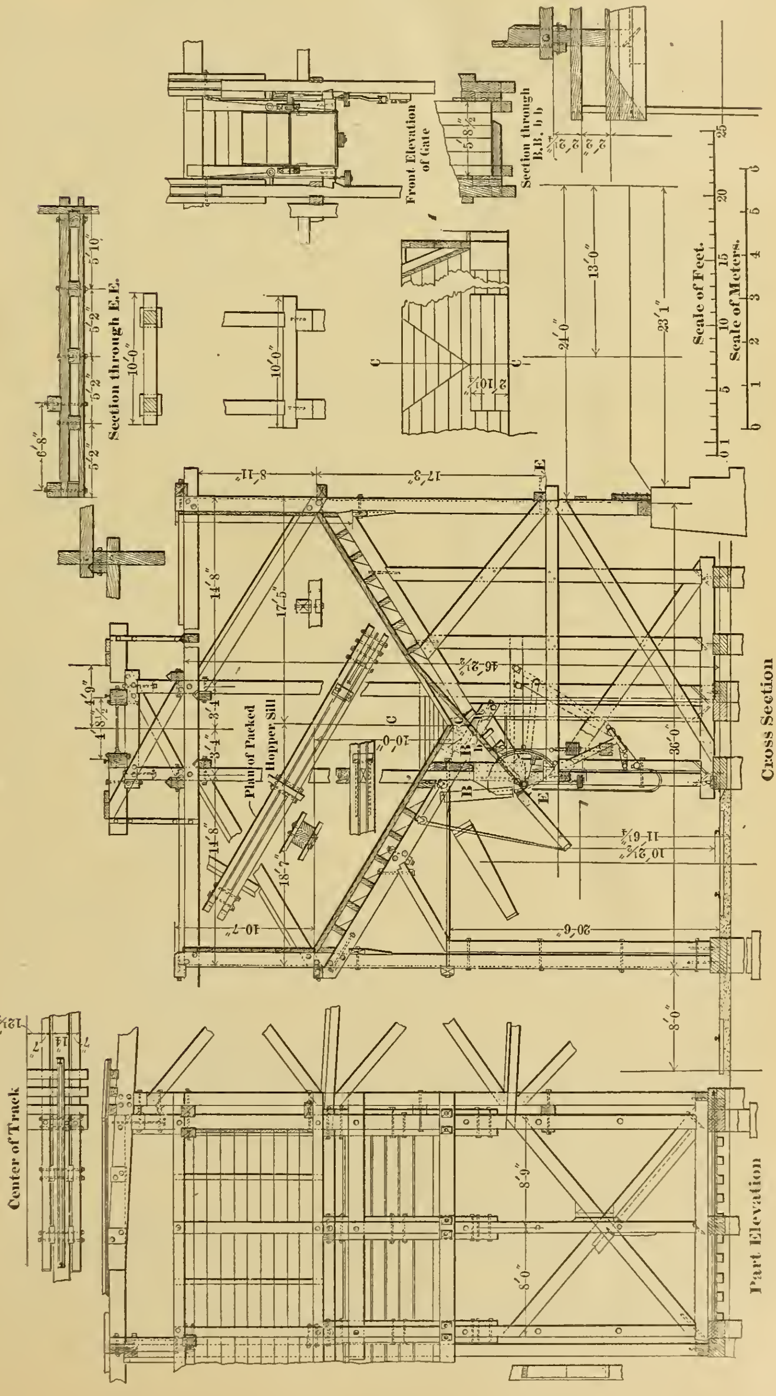


Oakland Distributing Bunker.

approaches the trestle on a run, and pushes the loaded cars ahead to the top of the bunker. Here the cars are, at present, unloaded by shoveling, but hopper-bottom cars are intended to be used. The shoveling here does not amount to very much. Most of the coal is simply pushed overboard.

At the further end of the bunker there is a heavily constructed buffer, to prevent accidental overrunning.

Engines to be coaled are run over the scales, and the tender is weighed and registered. The engine then runs under the bunker. The chute is lowered, the gate opened, the tender filled, backed to the scales



COAL BUNKER, SAN LUIS OBISPO YARD.

and weighed, and the amount of coal is registered. A duplicate tag is given to the crew, showing coal received by them. The work done with this coal forms a part of the engineer's and fireman's record.

Previously to the fall of 1894, when the distributing bunkers at San Luis Obispo were built, the operation of the gates through which the coal is delivered was a source of constant complaint. The gates were of the ordinary upward sliding kind, worked with levers. They were made of boiler plate, had angle iron frames, and were provided with a cutting edge at bottom to enable them to be closed through the stream of coal. Frequently—in fact usually—closing was prevented by a lump of coal or of slate. A pinch bar was then driven into the wood over the gate, and the cutting-edge forced down. The woodwork was badly torn up by this, and coal frequently overran the cars, sometimes burying them before it could be stopped. Sometimes this could be obviated by partially raising the chute until the coal was brought to rest, then digging out the impeding chunk, forcing the gate down, emptying the chute and pulling it up again, before the train could pull out.

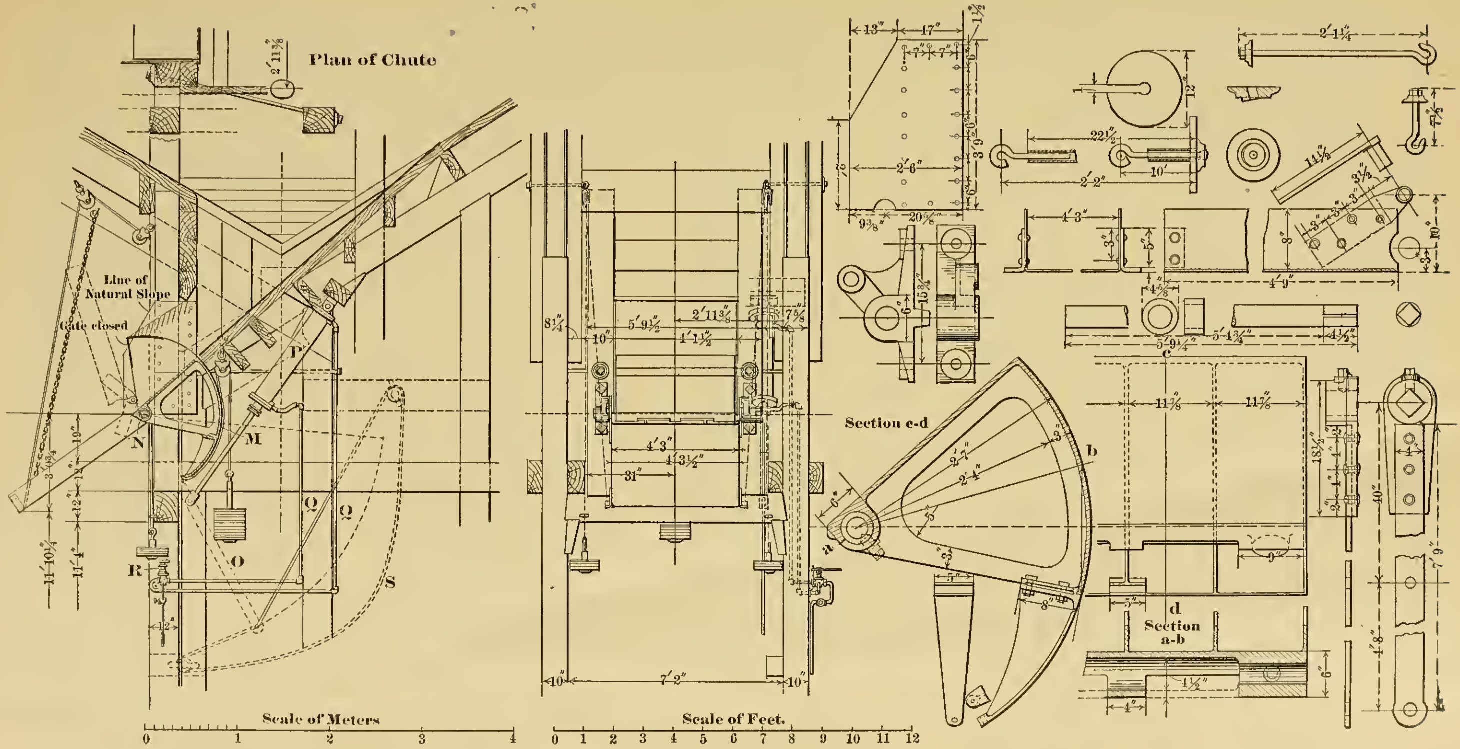
In the Port Los Angeles bunker we put a cast-iron rack behind the gate to give a purchase for the pinch bar. This saved the woodwork, but the other troubles remained.

A consideration of these difficulties led to the development of our gate and chute. The principle is simple and obvious. It amounts to placing, beyond and away from the opening of discharge, a removable retaining wall, which, when closed, rises to the line of natural slope of the top of the coal, and, when open, falls to the level of the floor of the chute of which it then forms a part. In closing, large lumps either stop behind it, or roll over it.

Having decided upon the principle to be employed, several methods of application were considered. The most obvious was to push a flat gate up through the coal until the line of repose was reached. This involved stiff construction, rollers, guides and other complications. These considerations brought us to the rotary gate, of which there may be two forms, one having its pivot next to the bunker, and the other, as adopted, having its pivot away from the bunker. Our reasons for preferring the latter are, that in closing its motion is in the same direction as that of the coal, so that the momentum of the stream is stopped gradually, and when open the back can be made to form part of the chute. Besides, the details seemed to be simpler.

When the first of these was made, it was so constructed that the bottom of the hinged chute, when up, closed against the upper edge of the gate. This was to avoid the splash when commencing to fill an empty bunker. Experience has shown this to be unnecessary.

The gate *M* is pivoted at *N*, and the gate is actuated by the hand



ARRANGEMENT AND DETAILS OF COAL-VALVE AND CHUTE.

lever *O*. The gate is of cast iron and has no finish except where bored for the pivot shaft. It and the lever are counter-weighted so that it always tends to remain closed except when wide open. It is then on a balance.

As a further convenience for prompt operation, and where we have a compressed air installation for working our signal systems, there is coupled to the lever *O* a small air cylinder *P*, oscillating on a pivot at one end, supplied by the pipes *Q* and manipulated by the four-way cock *R*. The pipes are fastened to the woodwork, and have hose connections to allow the cylinder to oscillate. In this case the line *S* for working the lever is only precautionary, to provide for failure of the air. This arrangement is adapted for Oakland and Rocklin bunkers. For San Luis Obispo the lever is worked by hand, and the line *S* is run to a place convenient of access to the fireman. We can, if we choose, arrange this last bunker for air by connecting the air cock with the brake hose of the engine, so that each engine, while coaling, will furnish its its own compressed air.

In every case the entire coaling is performed by the fireman.

In case it should be advisable to expedite coaling by having more tracks under the bunker, the seven bents of the trestle next to the bunker will be dispensed with and an overhead bridge substituted for them, so that a coaling track may be run on each side of the center. This will leave sufficient space in the center, between tracks, for efficient bracing.

To summarize: We now discharge a ship quickly and with much less shoveling than formerly; load flat cars for distribution with no shoveling; fill the distributing bunkers with little shoveling (none when our hopper cars are at work); load the engine without the shovel; fill the tender with ease and certainty; minimize breakage and have an accurate account of the coal used, to check against the tonnage and mileage of work done with it.

DISCUSSION.

Mr. Richards.—Mr. Isaacs' paper is very complete. The bucket and its operation are extremely simple. He says the Eastern buckets involve from two to four times as much detail. I have had occasion to observe different styles of grab buckets for forty years past, and I have the principal ones pretty clearly in mind. Certainly none of them are so simple as this one that Mr. Isaacs has described. I think it is very creditable to our engineers on this coast.

Prof. Wing.—Mr. Isaacs, in introducing his paper, said they were warranted in increasing the expense of handling the coal in order to

expedite the unloading of the vessels. The fact seems to be brought out that the ratio of live weight and dead weight is less than in the old form of bucket, the number of men is reduced and the rapidity of operation is increased. I would like to know if he can give us any information as to the relative cost of the two methods. It seems to me the cost must be much less with this style of grab bucket than with the old style of bucket.

Mr. Isaacs.—I said that I thought the company could have afforded, if necessary, to pay more for a quicker dispatch in unloading coal. As a fact, we obtained a more rapid discharge at less cost. The speed of hoist is about the same in both. The dead load with our grab buckets is equal to the useful load, while in the old method the dead load was twice the useful load. Taking into account the diminution of the number of men, I think I can safely say the cost has been reduced one-third.

Mr. Curtis.—I know it is fully that.

Mr. Isaacs.—This grab bucket discharges 3,800 pounds of coal at a single lift, while the old type of bucket discharges 700 pounds, and makes as many trips as the other. The full capacity of the coal bunkers represented on the diagram is ten tons to the foot run. The Oakland bunker is 200 feet long, and has 2,000 tons capacity. The bunkers at San Luis and Rocklin are 300 feet long, and have a capacity of 3,000 tons each. That at Oakland wharf is 400 feet long, and has a capacity of 4,000 tons.

Mr. Isaacs.—The largest of our colliers hold 4,000 tons. The coal bunker at Port Costa is 800 feet long, and holds 8,000 tons, or the cargoes of two colliers. The coal bunker at Port Los Angeles is the same.

Prof. Soule.—Did you notice any considerable reduction in the breakage and powdering of the coal by the use of these buckets?

Mr. Isaacs.—That is a question difficult to answer as to definite amount. We know that we did lose a good deal by breakage, and that we have obviated much of the loss by having a lower drop for the coal.

Prof. Soule.—It was a question with me whether the driving action of the bucket into the coal would not tend to grind the coal more than shoveling it into the bucket, as before.

Mr. Isaacs.—Probably it would do so a little, by lumps being broken in two from coming in between the jaws.

PRACTICAL NOTES ON UNDERGROUND ELECTRICAL SERVICE.

By E. J. Spencer, Member of the Engineers' Club of St. Louis.

[Read before the Club, January 22, 1896.*]

It is a fact not generally known—at least I have but once seen it commented upon—that the inventor of the telegraph used underground wires in his first attempt at commercial telegraphic installation. One of the exhibits that we lost for lack of space at the World's Columbian Exposition was a lot of antiquated instruments, a length of cable, and a plow drawn by oxen—the relics now in possession of the Baltimore & Ohio Railroad of the first telegraph—the plow used in opening the trench, the cable laid therein, and Morse's earliest instruments. It was about 1832 that the first section of the proposed telegraph from Baltimore to Washington was laid. The section was five miles in length, extending from Baltimore toward Washington. At great expense Morse and his supporters had made a leaden tube into which four wires had been drawn. These wires had been insulated by a wrapping of cotton which was painted with shellac. Through this cable the futile effort was made to operate the Morse telegraph. It is reported that Morse himself was discouraged and dismayed at the outlook, when one of his associates suggested that they put their wires in the air. This was done, and the system worked. Thereafter, all effort at underground service ceased, and the search for an insulated cable was limited to means for crossing rivers, etc.

Upon completion of the Philadelphia and New York line in 1845, an effort was made to convey the messages directly to New York City by wire under the Hudson River. This was a failure, however, and for some time the messages were conveyed by boats. In 1842 a copper wire, wrapped with hemp string, and coated with india-rubber and pitch, was laid from Governor's Island to the Battery in New York, but refused to work. In 1846 a similar arrangement was encased in a lead pipe, and laid across this channel, but also refused to work. The probability is that in none of these cases was the rubber vulcanized, as it was about this time that Goodyear made his great discovery, giving to rubber a value in the arts that it never could have attained in its raw state. Gutta-percha was introduced in 1847.

Experience abroad was much the same as that of Morse. In St. Petersburg Jacoby used cotton-covered wires sealed with rosin into a leaden pipe. But the insulation cracked and the cable broke down.

* Manuscript received April 18, 1896.—*Secretary, Ass'n of Eng. Socs.*

Rubber and gutta-percha were recognized as the only insulators with the prime physical requisite, viz.: that of flexibility; but in earlier days of limited facilities of transportation, rubber and gutta-percha were too expensive for use, except in case of submarine cables.

In 1856 began the commercial production of paraffine, which quickly assumed an importance in the manufacture of electrical apparatus, house wires, etc. By this time the use of aerial wires on poles, with glass insulators, had proven so satisfactory that there was no demand for underground cables for telegraphic purposes. One enthusiastic individual broadly patented the use of paraffine and its oils as insulation. Many years afterward, in the early days of electric lighting, he displayed wires, cotton covered, led through tubes in which oil was forced to circulate. The insulating power of the oil was remarkable. If a break occurred at any point in the insulation, the oil quickly closed upon it, reproducing the insulation as good as ever. The exhibit was sufficiently attractive to enlist considerable capital, and a commercial system of lighting was, I believe, actually installed after this model. The evident objection of uncleanliness, and the many physical difficulties encountered in such a system, caused its abandonment. Oil is now used in a limited way in the insulation of transformers, and other stationary apparatus, under a very high electrical pressure.

The first Atlantic cable was partly laid in 1856, and the first cable was completed in 1858, but the service was never satisfactory; and not till the second cable was laid, in 1866, was the Atlantic cable a commercial success.

In England, probably due to the existing cable factories, telegraph cables were laid underground as early as 1852. These were gutta-percha cables similar in characteristics to the Atlantic cables.

In Berlin a committee of savants had examined carefully into the failure of cables previously manufactured, and had reported that this was due to cracking of the insulation when bending cable in the process of manufacture, or in the course of transporting into place; the ultimate destruction of the cable was apparently just as sure whether these cracks were large or microscopic. The committee recommended—

First: That the insulation be put on in layers concentric with the core, thus permitting a slipping of layers in bending, and the interruption of the continuity of such cracks from copper core to the exterior.

Second: That the insulation be of such viscous character as to act as a solid when forced into these jute or fiber layers, but with sufficient fluidity to run together in case of incipient cracking.

The effect of this recommendation is seen in the construction of the Siemens' cable to-day; and thus early we have abroad the two great classes of cables, the rubber and the impregnated fiber.

There was no incentive in this period to cable-making in the United States. During our civil war many attempts were made to fire submarine mines moored in navigable channels,connected to the shore by insulated cables. They generally met with ill success on account of defective cables. This was notably the case in the James River, "where a United States frigate hovered" for four hours over a mine consisting of a boiler shell filled with "several thousand" pounds of gunpowder and which refused during this entire period to respond to the frantic efforts of those on shore to make it explode.

There is at our United States Torpedo Station at Willet's Point in New York harbor a museum of submarine torpedo development. It is with the blood tingling with resentment, the cheek mantling with the blush of shame at our own impotence, that we turn to the evidence of our own weakness in 1873; our inability to resent a National insult by a decrepit European power; our perfect panic over the possibility of an attack upon New York City itself, following on the heels of the *Virginius* affair; and our own puny efforts to supplement our miserable land defenses with a defensive system of submarine mines that never would have worked because of lack of reliable insulated cable to operate them with. The incident was happily repaired by the explosion of twenty-one blasts of powder by a Spanish gun-boat in salute to the United States flag. But Congress was awakened finally, and a move made toward the rehabilitation of our navy, resumption of work in coast defense and the purchase in England of sufficient submarine cable to adequately supply all our important harbors with an efficient system of submarine mines.

Up to 1878 we had wires and cables for telegraphic service only and the overhead wires multiplied almost imperceptibly. In 1878 we were blessed with the advent of the telephone, which made gigantic strides in our cities, telephone wires within a few years many times outnumbering the telegraph wires. At about the same time we got our first electric light, but the development of this industry was much slower than that of the telephone.

About 1882 the electric railway was introduced, and by the end of 1886 we had roads on three different systems in eight cities. In 1887 the Sprague system was made a success in Richmond, Va., and the following year we find all these various systems absorbed by three giant rival electrical corporations, and the attention of the various inventors directed toward perfection of detail, standardizing of manufacture and the study of economy of manufacture and of operation. With the latter came the introduction, in addition to the trolley wire, of the heavy feeder systems now prevalent in electric railway operation.

Prior to this the extension of high tension arc lighting and the

alternating system of incandescent lighting had brought about very unhappy relationship between the electric lighting and the telephone interests. The telephone people had evidently raised the cry for putting the lighting systems under ground, for at the first convention of the National Electric Light Association, at Chicago, February 25, 1885, the entire discussion was directed to the existing demand on the part of the telephone companies for the forcing of electric lighting wires underground, because of their interference with telephone wires and telephone service. A committee was appointed to report at the next meeting of the convention. This report was made by Mr. R. W. Pope, who recites that the only experience thus far available in the United States, was that of the Western Union Co., who ten years before had put down English gutta-percha cables drawn in cast-iron pipes along Broadway in New York City. The insulation was destroyed by adjacent steam pipes, and the entire system abandoned as a costly failure. The convention then resolved unanimously that it was advisable to relieve the streets of the great burden of the telegraph, telephone and fire alarm wires, but that the heavier, stronger, better constructed lighting systems should remain overhead. The convention, however, did a wise thing in appointing a committee to follow the work of the New York Commission of Electric Subways appointed under authority of legislative enactment of 1885; for it was due to the vigilance largely of this committee, that the work of a non-expert Commission proved, from a technical point, so substantial.

At the convention of February, 1886, this committee reported that they had attended all the public meetings of the Commissioners of Subways, and had examined minutely over one hundred plans presented the Commission. Meanwhile the Commission, after considering all the plans presented, and the criticisms of this committee, decided that it was unnecessary to follow any patented scheme, and outlined the true requirements of a subway system — viz., a duct, permanent in its character, accessible at intervals by means of manholes, for the drawing in of cables and the tapping on of service connections, the cable to be made complete within itself with all necessary insulation.

Disappointed patentees thereupon had the subway law and the action of the Commissioners thereunder declared unconstitutional and improper. This caused a delay of a year, when the present Board of Electrical Control was constituted.

Meanwhile electrical engineers were working energetically at the problem. The American Institute of Electrical Engineers took advantage of the Electrical Exhibition of 1884 to meet in Philadelphia, when the attendance from abroad was unusually large.

Mr. Berthon, of Paris, described the underground telephone system of that city. Mr. Calendar presented at length a paper on "bitite or

vulcanized bitumen" cables, which he stated had shown two years successful service in England. Mr. Preece, Chief of the English Postal Telegraph Service, confirmed Mr. Calendar's statements, and said that in his country they did not discuss the *possibility* of underground telegraph or telephone service; that with them it was simply a matter of first cost. If they had more than fifteen wires to run in a trunk line, it was cheaper for them to go underground.

But these electrical engineers had more to contend with than the single engineering problem of putting their wires underground. In the National Electric Light Association they came in contact with the commercial feature of the problem, and again and again they uttered their semi-annual protest against the enactment of subway laws applicable to arc lighting wires, in one instance stating that the cost was prohibitive; that while the overhead arc wires cost 1½ cents per foot, the underground would cost 6 cents per foot. The fact is that in these days arc-lighting companies are compelled to pay almost twice the latter price for a first-class cable.

In 1888 (May), Prof. Plympton described the Brooklyn system of subways, enumerated the failure of cables therein, and stated that in no instance had arc-lighting wires been successfully buried.

Meanwhile the new Subway Commission had, under the advice of their attorney, forced all issues in New York City by actually constructing subways. Their engineer, before the National Telephone Association's Convention, September, 1888, reported about 2,500,000 feet of single duct construction complete in 37 miles of trench—19½ miles for telephone and telegraph, and 17½ for electric light. Mayor Hewitt, in August, 1888, had opened the Electric Light Convention in New York with a very happy address of welcome, but ending in a strong appeal to the convention to take up and solve the problem of putting their wires underground. But the cost to the already overburdened companies seemed beyond the possibility of financing, and the question was shoved off until the next convention, with the usual resolution in favor of putting the telephone and telegraph wires underground, and leaving the electric light wires in sole possession of the air.

The situation in New York City was now intolerable. Rival companies entered the same field. No regulations had ever been promulgated for the control of overhead construction. Pole lines existed upon either side of many streets; and as many as three pole lines were consecutively erected along the same side of one street—each line taller than its predecessor. Private telegraph lines had given way to telephones, and the disused telegraph lines had been abandoned to their fate. Entire trunk lines were abandoned in favor of new lines along better routes. Rival companies sought each other's customers

and added their service connections, leaving the old ones in place. And with all, the lighting companies had been compelled by the insurance companies to make use of a grade of wire whose only recommendation was that it was not so inflammable as the ordinary insulation of to-day. The insulation consisted simply of a tape impregnated with white lead. The insulation was no protection from shock, and much worse than bare wire, from the false sense of security that its presence on the wire might give to the uninstructed lineman.

Fire, shock, injury, death, were of so persistent recurrence that the authorities grew desperate. Finally, on October 12, 1889, a Western Union lineman was burned to death almost in front of the Mayor's office. Immediately Mayor Grant issued orders that all electric light lines not properly constructed and insulated should be destroyed. The work had barely commenced when enjoined by Judge Andrews on the representations of the companies that the Western Union's man had been shocked by his own wires; that the electric light wires were well constructed in accordance with the underwriters' requirements; and that the authorities of the city of New York had never prescribed any standard of line construction, nor indicated any specific defects to be corrected in existing lines. Matters thus remained in *statu quo* until another terrible death of a lineman, almost in reach of a crowded platform of the Ninth Avenue Elevated Railway station, at 155th Street, again wrought up the public's fears to the point of frenzy; and the Appellate Court, on December 13, 1889, vacated Judge Andrews' order, on the ground that dangerous wires were a public nuisance, and that the Mayor, or Commissioner of Public Works, the Board of Health, or any citizen would be warranted in the abatement of such a nuisance, even to the extent of the destruction of the lines themselves. Thereupon began a slaughter of the poles. Before January 1st, 4,772 poles, carrying 5,615 miles of wire, were removed from the streets. New York was in darkness, and not before the middle of February, when the first underground circuits were put into service, did a single arc armature turn over in public lighting service. The writer was called to New York to immediately look after the interests of two of the offending electric lighting companies, and to advise and assist two others belonging to a friendly faction. An immediate examination and test of cables available was made with the assistance of the officers of the U. S. Torpedo School, resulting in the contract for the entire output from two of the cable manufactories for a period of several months. The prices paid were exorbitant, but I am happy to say that every cable is in service to-day and apparently as good as the day put down.

From this time, therefore, dates the beginning of commercially successful underground electric lighting. During the past five years senti-

ment of antagonism has been gradually lessening on the part of the operating companies; and to-day we find many of them, of their own volition, placing their heavier wires underground. This is notably the case in Boston, where the narrow, crooked streets prevent the proper guying of pole lines to carry the heavy feeders required for railway service, and this part of the system is largely underground; and in recent construction in Chicago, where it was a physical impossibility to carry on pole lines the 75 heavy feeder sections used in the operation of the West Chicago Street Railway Company's lines. In both instances, however, these underground cables are going in in districts where under terms of franchise, overhead wires are permitted.

I have already stated the requisite of a subway to be purely the mechanical protection of the conducting cables. These two—the subway and the cable, may be combined in one, as in the Edison system; or subway and cable may be separate, as in the drawing-in system of New York. The Edison System consists of copper rods which are wound with jute, bound together and inserted in a wrought-iron pipe. A melted compound of wax, bitumen and linseed oil is then forced into the pipe, completely filling in all intervals between pipe and jute and copper conductors. These pipes, or "tubes" as they are called, are laid in an open trench end on, the conductors, three in number, projecting about three inches beyond the end of the pipe. The several rods are then connected end to end by connecting lugs, and a cast-iron box then placed over the joint thus made, and filled with a hot melted compound that never completely solidifies. If a connection to a customer is required, special three-way connecting lugs are used and a cast-iron three-way or tee-box permits the connection of a tube at right angles to the street line, directly into the customer's cellar, as in gas service. The straight-away boxes and the tee-boxes are interchangeable, so that the latter may be at any time substituted for the former, and service connections made at every joint at intervals of 20 feet 6 inches, if found advisable. The trenches are then filled in, a plank being commonly laid over the top of the tubing, in order to protect from the blows of a pick in subsequent street excavation.

The difficulty with this system is the necessity of reopening the street to lay additional or larger tubes as the system grows. This has been met somewhat by superposing in part the drawing-in system with spare ducts for additional feeders, the main or distributing tubes being put in of sufficient size to meet reasonable increase in business. Let me say that from its inception the Edison system has been for cities a complete system from dynamo to lamp, with every detail carefully worked out, and put in without makeshifts, *underground, and with the intention of its staying there.* These tubes have been purchased at prices simply

beyond conception, at times when copper rods and pipe were high, and the skilled labor necessary to handle such work much overpaid; when the system was protected by strongest patents, and users expected to pay right royally for the privilege of using. But we, who are using other systems, are confronted with the fact that, without exception, these Edison stations are making money to-day. This we cannot say in many other instances.

The second or drawing-in system consists of one or more ducts with necessary arrangements to permit of drawing in insulated cables and connecting them at intervals to house services.

It matters not whether the conduit be of any one of the systems in common use, provided the ducts be straight, smooth, sufficiently large, and with manholes at frequent intervals, so that the strain in drawing cables through be not so great as to injure them.

The various drawing-in systems are briefly as follows:

I. The Dorsett.—This has been used to a limited extent in New York, in Chicago, Minneapolis and elsewhere and is the original system put in in the city of St. Louis by the St. Louis Underground Service Co. It consists of asphaltum blocks 4 feet long by 1 foot square with 2½-inch ducts molded throughout their length. It is a relic of the days when it was supposed that the conduit itself should be an insulator—a feature that we now little care about. The ducts, if well laid, present a smooth surface in every way desirable for the drawing in of cables, but the size of duct is unfortunately too small to take in the present large sizes of telephone or telegraph cables, or the largest railway or lighting feeders of the present day.

II. The Johnstone.—This is a very completely worked out system, having in its lower section what are known as trunk ducts, running uninterruptedly from manhole to manhole, and in its upper section what are called distributing ducts, the cables therein being accessible at intervals for the purpose of making house connections. The system is entirely one of iron castings in 5-foot sections, the lower sections carrying the trunk ducts, the upper section or cover being removable, exposing the cables therein, and being made interchangeable with another cover having provision for handhole and lateral outlets for house services. The system was early adopted in New York, but abandoned because of the inherent expense and a disagreement with the patentee as to the royalties to be paid for its use.

III. A largely used system is that recently installed on Olive Street, in the extension of the St. Louis Underground Service Company's system to the Postal Telegraph Company's operating room in the Laclede Building. It consists of sheet-iron riveted pipe lined with cement, the interior of duct being 3 inches. These ducts are made singly in

8-foot lengths with male and female spherical joints at the ends. This construction insures good joints, comparatively few in number, and with excellent interior surface for drawing in cable. The ducts are laid singly in a row upon a base of concrete and in cement mortar. This, and all following systems, have the great advantage of adaptability to service requirement, in that any number of ducts from one up to the maximum can be laid along a certain route, and further, that there is a certain flexibility at the joints, permitting spreading of ducts, or slight variations in alignment to avoid obstructions in the trench.

Instead of the sheet-iron cement-lined duct thus described, we find in use wooden ducts of creosoted pump logs or slight modifications thereof, or ducts made of glazed tiling; of wire gauze supporting a molding of cement; of molded cement tubes; or, as in the later construction in the city of New York, of wrought-iron pipe. All these classes of ducts are generally laid as described above, in cement mortar on a concrete foundation, with a wall of concrete on either side, and a protective covering of plank or concrete.

At street intersections these ducts, as also those on streets at right angles, are brought into a common manhole. The cables are fed from drums on the street down through the manhole cover and into the ducts and then jointed in the manhole to the lateral or extension sections as the service may require. As these ducts end on the face of wall of the manhole, they are about $4\frac{1}{2}$ inches apart center to center. The cables coming through them are bent around and carried along the walls of the manhole on racks, until they enter the ducts on the opposite side. This is necessary in order to leave a clear space in the center of the manhole for men to work. It is easy to see that with a large number of cables even the most careful arrangement on racks involves a very close bunching of these cables in their progress from the duct mouth to the racks, while the short bending of the cable at the duct mouth at least does not increase the power of the cable to resist rupture and burn-outs. It is at this point almost without exception that break-downs occur, and at this point the break-down becomes most serious as the burning cable injures the one in contact with it; this gives way, then another, until every cable in the manhole may be put out of service. It is for this reason that the cable munufacturer prefers smaller subways, fewer ducts and separate subway for the wires of different classes.

As to the cost of subways, this will depend upon the character of pavement, of subsoil, the number of obstructions to be removed and replaced or avoided, and the frequency of manholes. It is evident with 3-inch concrete protective wall a subway of one or two ducts is comparatively expensive. For twelve ducts or over the cost per foot of subway is almost proportional to the number of ducts and can be assumed approx-

imately as from $1,200 to $1,800 per duct per mile. Messrs. Maver & Lauterbach, of the New York Subway Company, are responsible for the statement (February, 1890, meeting of the National Electric Light Association) that the subways in that city cost as a minimum $3,000 per mile. The Subway Company charges an annual rental of $1,000 per mile of 3-inch duct. This has proven a heavy burden upon the electric lighting companies; the prices for service are necessarily excessive and the extension of business very slow.

One word as to the room necessary in the streets for subway construction. There has been much unnecessary misapprehension regarding this point. A single 3-inch duct will take a 100-pair telephone or telegraph cable. The equivalent pole line would be one carrying twenty 10-pin cross arms. For electric lighting and power the same concentration is not possible, although I have here a single cable capable of carrying 1,500 horse-power, the equivalent of nearly four of the largest sized cables ever strung overhead — such as you will note along the east side of Fourth Street on the new Arsenal Street Railway pole line. Four of these cables in the air require a space of 4 square feet; this cable in the ground with its duct requires a space of 20 square inches — about $\frac{1}{30}$ of the air space. Much misunderstanding too seems to have existed regarding the possibility of one company blocking off future competition by its subway construction. This is an error. Ordinarily subways are constructed in the unoccupied area vertically between the water mains, which in this climate are laid about 5 feet below the street surface, and the gas mains, which are generally laid as shallow as possible. In this space of 36 inches, with a roadway of 30 feet width, could be placed 750 ducts carrying 150,000 telephone and telegraph wires, or cables carrying 1,125,000 horse-power; and without undue expense, by constructing manholes of proper depth, such a subway could be carried under or over, or communicate with a similar subway along an intersecting street, the manhole depth being adjusted so as to go through the space between the water pipes and the sewers, or, if necessary, under the sewers. This is an extreme case, but it serves as an illustration. But, as a matter of fact, in a space of 5 feet between curb line and center of street there *could* be constructed four separate and distinct subways giving to each of four companies fourteen ducts, capable of carrying for each company 2,800 telephone or telegraph wires, or cables carrying 21,000 horse-power. The same thing *could* be repeated on the other side of the street, and the railway companies carry as much through the center of the street. All this without covering up water and gas pipes or going, except at street intersections, below the depth of 5 feet under the street surface.

As for the legislation to accomplish the undergrounding of wires, I hesitate before men who have given this subject so much practical thought

to speak. The general view taken by the courts in this matter is that cities have a right to regulate the installation of electric wires and can compel the same to be placed underground. Where existing companies are in the possession of overhead rights and making use of same, these can only be taken away collectively; telephone, telegraph, police and fire alarm telegraph, electric light, power and electric railway must all go underground together. But the manner of procedure must be such as to give to the servitor the equivalent right underground of its existing charter rights overhead. And the method of procedure must not work undue hardship (such as the allowance of too short time for the change) or amount to a confiscation of property (such as the taking away of rights of ownership and the substitution of leasehold rights, especially for a period less than that of the franchise); or the compulsory placing of the trolley wire underground where the expense amounts to confiscation and the practical results are doubtful. But every other existing wire can be placed underground in the business districts, without exorbitant cost and to the great advantage of the public and the operating companies.

If we approach the subject in a spirit of justice and of fairness to our electrical servitors, I believe that there will be no trouble in securing the undergrounding of all wires (except trolley wires) within the limits of our business district before the year 1900. This Club, representing the leading corporate interests of this city, representing the leading taxpaying interests of this city, is in position to use its good offices in bringing about a full understanding on any points of difference between the electrical corporations and the city's legislators. This done, right merrily will we see the poles fall on Broadway, and Fourth Street, and Olive Street, and Pine and Chestnut Streets, and the city take on an improvement in appearance that will astound the oldest inhabitant.

I have here for inspection of those who desire to look them over the underground franchises of the largest companies in the country, the Edison Companies of Boston, Philadelphia, St. Paul and Milwaukee. I have also a typical electric railway ordinance in that of the North and West Chicago Street Railway Companies; also the franchise of the Northwestern Telephone and Telegraph Company operating the exchange of St. Paul and Minneapolis.

I have also a number of samples of cable which I will pass around for examination. They are all labeled so as to indicate their use and service capacity.

Editors reprinting articles from this journal are requested to credit both the JOURNAL and the Society before which such articles were read.

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RECENT IMPROVEMENTS IN MAINTENANCE OF WAY.

BY BENJAMIN REECE.

[Read before the Technical Society of the Pacific Coast, April 3, 1896.*]

WITH the constant increase of railway mileage in this country, the struggle for existence has been very bitter, and doubtless will become more so.

The construction of railways has been encouraged by the general public for the purpose of stimulating competition, and doubtless many lines have been poorly located, and still more poorly built, for the mere profits of construction. These have been developed generally by promoters and speculators, who have availed themselves of the easy money markets which prevail at times when railway securities are in special demand, as in those periods of great activity and rise in stocks, which are generally known as business booms.

Lines thus built frequently enter into a competition in which rates are indiscriminately cut, and demoralization to railroads and commerce alike is threatened. Capricious and illogically cut rates are the despoilers of honestly managed properties and the debauchers of the public confidence. The lines which precipitate these struggles are generally those which are the least prepared for any permanent reductions.

The public, thus looking for competition and failing to recognize the difference between permanently low and cut rates, is impatient at

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any thought of pools or combinations, which in themselves would check many of the evils which the Interstate Commerce Bill is intended to correct. The gradual lowering of established rates has been, and in a measure it will continue to be, the necessary consequence of our economic conditions, and in the ultimate struggle the lines of low capitalization, consistent with a minimum of cost for repairs, will ultimately set the pace.

Evidently this implies a management in which the wasteful expenditure, or still more costly neglect, in maintenance of way must be corrected.

Even now we are confronted with a constant lowering of rates which, in many instances, has become necessary in order that we may market our products at all. Fifteen years ago our Western farm products had almost full possession of the markets of western Europe, but the extension of railways in Russia, Hindoostan and South America has resulted in the opening up of so much new territory that the prices of wheat have been reduced one-half, and in the rapid colonization and development of Africa appears the specter of a still more dangerous rival.

With this constant lowering of the prices of Western products freight rates must logically fall, for our railways carrying seaboard shipments, which really control the prices of our superabundant products, are no longer restricted to national competition, but find themselves in active rivalry with the developing railway systems of the Continents.

The panic of 1873 was precipitated by excessive railway construction, but that only involved a waiting for this rapidly developing country to restore the equilibrium. This was much aided by the general adoption of the Bessemer steel rails, which have saved to the railroads those enormous expenditures which, even under the light traffic of that time, the rapid destruction of iron rails had involved.

In 1879 the revival came, and with it came an increase in loads for cars, the first suggestion being to load the cars of 12 tons capacity, which then prevailed, up to 13½ and as high as 15 tons. This was resorted to as a quick and ready means of increasing the carrying capacity of the lines which at that time was utterly inadequate to convey the tonnage to be hauled. From that time dates the construction of cars of increased capacity, until 40 and even 50 tons per car load has now been reached.

In connection with increased car loads is also noted the demand for increased train loads involving heavier motive power, which has proceeded with undiminished energy. Indeed, in general terms, it may be stated that the period from 1880 until the nineties was one in which economies in the cost of transportation proper was the ruling thought.

But time as well as cost of service is frequently the basis of competi-

tion, and it has occurred that while wheel loads have been increased the speed of trains has also been accelerated. On but few railway lines did the improvements on the track keep pace with the severity of the service required of them, and not infrequently the road departments on railways were engaged in a hard fight to keep their tracks safe for the running of trains. It was at this juncture, from the very exigencies of existing conditions, that we can date the recent improvements in the maintenance of way on many lines. To this general statement there are, of course, as you are aware, many notable exceptions.

The panic of 1893 proved an inexorable educator in pointing out the fact that the earnings of the prosperous must in part at least be expended in capitalizing the expenses of maintenance during the years of depression.

With decreasing tonnage and diminishing rates it was learned that money had to be saved even if money had to be expended for the purpose, and to those lines which, in large measure, have fairly maintained their tracks in the past must we look for existing as well as prospective improvements in maintenance of wa

The improvements may be classed into those of refinement of track and of those permanent improvements looking to a diminution in the cost of repairs; but as, in a great measure, these betterments are largely obtained by the same methods I will attempt no division of them. The one, of course, has been rendered necessary by the marked tendency to increase speeds in passenger service, the other has been rendered necessary as an essential to survival, as on many lines the annual cost of repairs were so burdensome as to periodically call for the appointment of receivers, which, in some instances, entailed the loss of the property, while in others it was employed as an instrument by which the physical condition of the road could be restored to where it should have been preserved.

On roads, both of high and low degree, there is considerable activity in providing a good ballast bed for the support of the tie, and to give stability to the track as well as to reduce the annual charge for labor, which had been required to keep in poor surface and line, track which had been formerly surfaced with the soil.

Gravel, cinders, furnace slag, broken stone and burnt clay ballast is being hauled, in some cases, two or three hundred miles, for the purpose of this important betterment, and wherever it has been done, the wisdom of the move is vindicated in the great reduction in labor, cost of maintenance, to say nothing of the saving to rolling stock, motive power, rails and fastenings, all of which were subject to the shocks and impacts due to defective surface and imperfect line.

Roads differ somewhat as regards sections of road-bed between

themselves, yet there is observed that greater attention is paid to their individual standards, and greater uniformity exists in this regard than ever did before.

A radical increase in the weight of rail section is also noted, the principal Eastern lines ranging from eighty to a hundred pounds per yard, while upon the coast I learn your increase is from sixty-two to seventy-five. These heavier rails, affording much greater stiffness as beams, results in less wave flexure, hence affords a more stable track, less undulation of rail, pulling of spikes, and not infrequently pushing of ties in the ballast, and the greater benefit derived from the heavier rail is to be found rather in the saving of labor than in the additional wear of the rail itself. In our American practice, we still adhere to the hook head spike, practically the same as was used with the earliest T-rails. While this subjects our tracks to more excessive creeping of the rail, which, however, is measurably reduced with the deeper, heavier sections, yet it does not pump the ties in the ballast, as is found to be the case with the tracks laid with T-rail screwed down to the tie on tie-plates, as in the Continent of Europe. In my opinion, the nearer the surface you can confine any vertical movement of your superstructure the more permanent it will be, and the less costly to maintain, and there has been but little tendency to depart from its use, although many improvements have been attempted with a greater or less measure of success.

As a fastening, the angle bar appears to be growing in disfavor. Much was expected of the long angle bar supported by three ties which was first applied on the West Shore Railroad during its construction in 1881 and 1882. That it has not given the satisfaction expected of it is evidenced by the fact that many of the lines who have used it have returned to the shorter bars. On the lines ranging through Indiana and Ohio, I have heard it claimed by engineers that, when tightly bolted, the long bars offer sufficient resistance to the expansion and contraction of the rail as to kink in the one case, with the tendency to break in the other. Of course, when the bolts are loosened, the joint is necessarily imperfect. Mr. Torrey, Chief Engineer of the Michigan Central, has been experimenting with rails, 500 feet and 800 feet in length, respectively, using expansion joints for same. These rails were very closely watched, observations being taken as to expansion and contraction three times daily. Mr. Torrey is so well pleased with the result as to make a further experiment covering a mile of track. As you all know, some lines have used and are using rails of 45 and 60 feet in length, with a view of eliminating the joints. Several new joints, generally patented devices, have been placed upon the market, many of them having secured recognition on important lines, and are said to be giving good results, covering from two to four, or even five years of service. The trouble with the

angle bar rests in its limited bearing surface under the head of the rail. This, in a few years, results in the wear of the angle bar and a corresponding wear of the under head of the rail at the ends of same. In 1879 I put in a cold cutting rail-saw to cut off the dipped ends of 30-foot rail, reducing them to 28-foot lengths. With these, I laid branch-track, attempting to use the old angle bars, but found a movement of the rail from the start. Upon examining the bars, I noticed them sufficiently worn, as to leave a well-defined piece of metal in the center, in the shape of an inverted V where the angle bar had been more or less protected by the expansion opening left between the rail.

It is because of this feature that nearly every joint of recent design involves the bridge affording the rail an undersupport resting upon and bridging the space between two ties. That a radical change in the fastening of rail joints will shortly come about I have but little doubt.

While the main expense of maintenance is that of labor, it is to be regretted that as a general thing the personnel of the section gangs throughout the country is deteriorating in the East, particularly the Italian is gradually displacing the older section hands. In the South possibly the negro laborer may be improving, certainly he ought to be if he benefits by experience. In the Middle States also the native German and Irish section hands are gradually giving place to laborers of a lower grade; this of itself demands more constant and better supervision and the introduction of all available checks upon them to secure that thoroughness of work which alone can make refined and enduring track. It is a good sign, however, that recently, while on an inspection trip on Illinois Central, I saw a roadmaster censured by the chief engineer because the new rail, just laid, showed a sixteenth of an inch open gauge.

After many years experience I am fully convinced that track can be laid to a perfect gauge in renewals at very little greater cost than when careless and hastily done. Such track, thoroughly tamped and well lined, is not only enduring, but the most economical in the end. The refinements of a main line are not required upon the branches, but even on these thoroughness of work up to the standard of excellence required, insures permanence and less cost than the constant botch work which not infrequently prevails on lines where the handcar, moving from point to point, is in more frequent use than other tools. The proper policing of the track is undoubtedly of great moral benefit to the man, but well defined lines, uniform section of ballast, and track properly cleaned of grass, is conducive to an *esprit de corps*, which is made manifest in more energetic and ultimately in more intelligent labor. In comparing the cost of maintenance on different lines in the various State reports and other sources, it has been my experience that, as a rule, on lines of similar traffic, those showing the cleanest rights of way, and best defined road-beds, have shown the lowest cost per mile.

Twenty years ago the cost of rail renewals, next to labor, was the largest item of expense. At this time, although the Bessemer steel rails were much more expensive than iron, yet they were being very generally introduced upon our railways, the enormous annual cost of the renewal of iron rails having almost threatened the life of our railway system. With the cheapening of coal, the development and opening up of Bessemer ores on Lake Superior, the cost of Bessemer steel rails has been so reduced that their present market price is not more than 40 per cent. of the cost of iron in 1872. Not so with ties, however. The gradual reduction of our forests, particularly in the older section of the country, has tended to a constant increase in their price, and where, under the moderate traffic of that early period, they gave service until removed by the cause of decay, they are now frequently destroyed prematurely by the action of the rail under the heavy wheel loads, higher speeds and increased traffic of to-day. So that while the cost of rail renewals were four or five times those of tie renewals in 1872, the figures were almost reversed and ties, next to labor, have become the most considerable expense in the maintenance of way, and the cost of tie renewals are now from two to four times the cost of rail renewals, according to the location of the line upon which the comparisons are made. For many years this question of ties had received but little attention. What had been true in an early day was supposed, or at least assumed, to be measurably true to-day. As the question was agitated and studied the question arose as to how the cheap softer woods could be made available for use under heavy traffic. Some of these woods are very enduring against decay. Such are the cedars of the Lake region, the cypress of the Gulf of Mexico, and the redwoods of California, but their usefulness was much impaired by reason of their cutting in and being destroyed by the action of the rails. Other soft woods which could be secured at low cost were susceptible of chemical action which would add greatly to their lives, but like the more enduring groups they were rapidly destroyed by the action of the rail. In the treating and mechanical protection of ties the Southern Pacific line has been one of the most fearless and at the same time successful pioneers.

Perhaps, in the whole range of maintenance of way, the most striking feature is the revival of tie or wear plates which are now being very generally used throughout this country and Mexico. Plates were early used, but were of such designs that they only partly saved the tie and introduced difficulties almost as objectionable as those which they were intended to correct. The first designs were based upon the mistaken assumption that the tie was destroyed by the direct crushing down of the fiber by the indentation of the rail, whereas the breaking down of the first wood cell is followed by rasping and throwing out of the fiber of

wood, due to the slight back and forward movement of the rail. Any one who has observed a cut tie must have seen that the cut sides are walled up almost as if cut with a saw. There is no drawing down of the fibers as would have been the case had it been the result of indentation. This error led to the idea that a greater distributive area was required, and induced the development of long wide plates to support the rails, whereas in fact it was only needed to confine and protect the wood fiber from being displaced by the rail, and thus confined, after being compressed so far, sawdust itself would have supported it. You will at once see that a long thin plate would necessarily curl at the ends and a constant thickening to avoid this evil was the result. The plates being loose would jump from the tie, give out a disagreeable metallic ring, and would indent the tie sufficiently to leave a receptacle for water, which the undulating rail acting upon the plate would literally pump into the tie, and hence cause premature decay of the tie under the rails. Nor was this all. The heavy plates working loose from the tie acted as anvils under the rail as they received the shock of every moving wheel. This led to a spotting of the rail by reason of lamination, and some 40 miles of such plates having a shoulder abutting against the outer flange of the rail were removed from the Pennsylvania over twenty years ago. The early experience with such plates was such that they were universally condemned, and it is only through the long success of applications hesitatingly made that the revival has become complete.

Before rail movements had been closely watched it was assumed that a well spiked and well bedded rail could be turned over by the moving train. It was also assumed that the engine exerted a direct lateral thrust, sufficient to overcome that exerted in the direction of gravity from which it derives its tractive force, the fallacy of this is at once apparent. This suggested the use of rail braces, which are now recognized as failures. It also suggested the outer shoulder on the plates, which, though of some little advantage in saving the spike from the wear due to the slight undulations of the rail, necessitates modifications of designs at once injurious to both tie and plate. The theory is that the shoulder will protect the spike from abrasion, but manifestly if the plate has a plain under surface, the rail pressing against the shoulder will cause the plate to impinge upon the spike and wear it away, where it cannot be seen, which is even worse than where the same conditions exist in the light of day, visible to track walkers and section men. This led to spurs, prongs and flanges which cut the tie transversely of the grain, in order to hold the plate securely against such movements, but with the constant vibrations of passing trains the transverse openings thus made in the wood are widened, and as the tie softens they loose their hold at the very time when the plate is supposed to be

of greatest value. The development of the last eight years has shown that where the hook head spike is used to fasten the rail to the ties, that any successful tie-plates must automatically unite themselves to the tie, becoming practically an integral part thereof. This has been fully accomplished by the use of plates having longitudinal flanges, which separate without splitting the grain of the wood, and so fix themselves firmly to the tie-plate in the general form of a channel iron, have been found very effective.

I need not call attention to the fact that the channel iron form is particularly well adapted to confining and protecting the wood fiber from displacement by the rail. I have seen a plate of this type $3\frac{3}{4}$ inches wide by 8 inches long protect a chestnut tie in the tracks of the New York, New Haven & Hartford Railway for six years, when adjacent ties unprotected had been cut down by the rail, having 5 inches width of base for more than an inch in depth. In the indentation of timber its structure is such that it is pushed out transversely and does not elongate, hence with timber at all fibrous such plates become tighter and tighter with use, and in the case of oak when being removed, I have seen them lift out bodily from a tie the wood lying between the flanges of the plate. Many minor changes might be enumerated, but time will not permit. I am, however, glad to say that more and more attention is being attracted to maintenance of way, and there is a growing disposition to select technically trained men for the supervision of the work, which gives promise of a wider field of labor for the civil engineer.

DISCUSSION.

Mr. J. H. Wallace.—Using, as we do on this coast, a soft redwood tie which is rapidly cut out under the rail, but which, when not destroyed in this way, will resist decay for many years (we have ties in sidings, that are perfectly sound after forty years of service), we early began experiments looking to the adoption of some method to prevent this cutting, and thus lengthen the life of the tie.

At first, we labored under the same mistake as others referred to by Mr. Reece, and supposed the wear was due to the crushing of the fibers of the wood by the load put upon them. With a view to overcoming this, it was at first suggested that larger ties be used, spaced closer together, thus endeavoring to diminish the pressure per square inch on the wood.

Efforts in this direction had not progressed far when it became evident that the wear under the rail was due not to the destruction of the fibers by compression, but to their being gradually ground or worn away by a slight longitudinal motion of the rail, aided by the sand and grit which found its way between the rail and tie.

The remedy for this is, undoubtedly, the use of tie-plates. As yet, our experience with them is limited ; but, so far as we have gone, we are very well satisfied they are going to make the redwood ties last about three times as long as formerly.

Mr. W. G. Curtis.—I might say, in corroboration of Mr. Wallace's remarks, that probably not one per cent. of the redwood ties removed from the tracks are removed on account of decay. The failure is almost invariably due to the cutting out of the tie under the rail.

About ten years ago we put some experimental plates upon the redwood ties on the shore end of the Oakland mole, watched their wear and kept a record of them. I thought I had the figures here, but find I have not. The ties were cut down about one and a quarter inches under the rail by the passage over them of about thirteen million tons of trains. The life of the redwood tie is not measured by time, but by the traffic.

We have ties in sidetracks to-day, a few, that were laid, I think, in 1856, forty years ago, and they are still perfectly sound and are good ties. Of course, but little traffic has passed over them.

We experimented on the Southern Pacific lines ten or twelve years ago with plates, and our course has been very much like that described by Mr. Reece. We had the idea at first that a greater bearing area was needed, and made very large plates. We were disappointed to find that they did very little good, and finally came to the same conclusion Mr. Reece has presented, that it is the rasping motion, the sliding motion of the rail upon the tie, almost imperceptible though it be, that cuts out the wood. We tried fastenings that would secure the rail, plate and tie more closely. In one experiment we used a "U" bolt passing through the tie, with the nuts at the upper ends, and washers so shaped as to engage the rail flange, in this way fastening the rail and tie together ; but that did not seem to meet the requirements either. As a result of our experiments, our conclusion is that a plate, to be effective, must either be very heavy or be attached to the tie ; and as a plate that can be attached reasonably well to the tie can be made very light, and at a much lower cost than a heavy plate, our ultimate conclusion has been in favor of the smaller plate attached to the tie.

METROLOGICAL STANDARDS AND GAUGING IMPLEMENTS.

By J. Richards, Member of the Technical Society of the Pacific Coast.

[Lecture delivered before the Engineering Classes at Leland Stanford Junior University, Palo Alto, Cal.*]

It is a curious and even anomalous fact that throughout the whole realm of nature there is no uniformity except in the element of time. The inevitable laws that govern forces and motion, the endless cycle of causes and results that form the basis of physical science, point to uniformity in matter as a sequence or condition of these invariable phenomena, but this is not the case. There is no uniformity in matter.

No two persons are alike. No animal, tree, shrub, plant, leaf or even a blade of grass has its precise counterpart in nature. Among a thousand faces that we know, each is distinct, and among the millions that we do not know this distinction goes on without any limit that we can conceive of. It is possible that no two grains of sand are precisely the same. There is no regularity of temperature or weather, no uniformity in matter organized, active or inert, so there is no fixed material basis from which a natural standard for metrology can be derived. Distilled water, we may say, is uniform in weight at some assumed level, the surface of the sea for example, but how are we to determine a specific quantity of distilled water or other liquid, without some means of measurement?

Lineal measure must be the base of all. By this are determined weight, capacity, surfaces, solids, and, indeed, all common measures. The metrical system is an illustration of this; the meter, an arbitrary lineal standard, is the base of the whole.

Some centuries ago this difficulty of standards became apparent, and there was a search extending over about two hundred years in attempting to derive from some natural source a lineal measure that could be appealed to in case of doubt, or the loss of standards derived therefrom.

This search for a natural standard for lineal measure in England and France forms a very interesting history that we need not follow out here, farther than to say that the two nations started out on different roads that after long and tedious experiment came together, because the search was abandoned by both countries.

The English scheme was to derive a lineal standard from time, or,

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as we may say, from the motions of the planets. Time is a constant and uniform element in the great economy of nature, divided with accuracy down from years to seconds, or, as we may say, with present knowledge, from centuries to seconds, and a measure if derivable from time could always be reproduced.

The method attempted in England was by the vibrations of a pendulum in a vacuum or at sea level in an undisturbed atmosphere. This was a very ingenious idea, and came near settling forever a standard for lineal measure. As a pendulum swings in equal time, irrespective of range, it is easy to adjust one to beat to seconds, and if this length could be translated to a measuring implement a similar standard measure could be derived in any part of the world at any time.

There arose, however, some serious impediments in these experiments, one of which you can easily imagine; that of determining the length of the pendulum after it had been adjusted to beat seconds. The method was to place fine pivot points at both ends of a symmetrical bar of metal, and then reverse it, to swing first on one end and then on the other, but there remained still the difficulty of transferring this measure, so the scheme was finally given up after a half century of experiment.

The French people attempted to derive a lineal standard from material nature, the ten millionth part of a quadrant of the earth's meridian. To determine this a degree of longitude was measured between Dunkirk and Barcellona, and the meter was derived from a subdivision of this distance, but there arose great contention over the method and results, and the French then, as the English had done long before, abandoned the scheme of a natural standard, and legalized the particular metrical standards then made, and took the required precautions, as in England, to deposit duplicates in different places, so that their loss could not occur. There was a great ceremony over this event during the reign of Napoleon II, and this arbitrary standard is, as you know, fast becoming that of the whole world, as it ought to do with all possible haste, being decimally divided.

When standards are arbitrary it is nonsense to talk of a national one. One standard is just as good as another in so far as authority is concerned. If any nation had succeeded in determining a natural standard, the case would be different, but an arbitrary one may be a yard, a meter or any other unit. There is nothing national about it, and cannot be.

The English, and to some extent the American idea of a meter is that it is a French measure, because France first adopted this unit, but being an arbitrary measure it is not French any more than it is English or American. It is only a matter of agreement, as the English yard is

with its division into inches and feet, with divisors of three and twelve instead of by ten, as we compute in common numbers.

I am sorry that the time at command does not permit more to be said of the curious facts and procedure that are embraced in this history of standards. It is extremely interesting, but not very useful in a practical sense, unless to dissipate some notions commonly entertained about such standards.

The true standard in this country is the meter, legalized in July, 1866, decimally divided downward to the millimeter, and with multiples upward the same, to the myriameter, but by custom, and following the British measures, our machine work is mainly with measures corresponding to divisions of a yard, with divisions downward of three and twelve, as before remarked, stopping at an inch, which is twenty times too large for convenience, and going up by factors of 5½, 40 and 8 to a mile, all of which is as absurd as it is inconvenient.

Other measures of weight, capacity, surfaces, solids, and so on, are as bad or worse, because we have two standards for weight and two for capacity, both in common use, divided in a manner that conforms to no conceivable system of order or relevancy, and explainable only on the grounds of accident, dating from a time and from circumstances that have nothing to do with modern methods—a tradition that would be out of place in the realms of imagination, to say nothing of the exact arts and sciences of our time.

The gauging implements now in use in this country, and by means of which the dimensions of machine parts are determined, are, as before said, derived from the British yard, expressed in inches and fractions of the same, mostly fractions, indeed all fractions, except for four implements out of a set of thirty to forty pieces, as any table of sizes will show.

These gauging implements consist of movable or adjustable calipering machines, fixed calipers, pins and collars, internal gauges, test rods, reamers, mandrels, and so on, adjusted to various degrees of accuracy; for example, to a five or twenty thousandth part of an inch in classes that are sold at different prices according to the accuracy guaranteed by the makers, as the published lists will show.

In 1860, when my connection with this matter began, there were no gauging implements in this country, except Whitworth pins and collars, imported at an expense of $300 to $600 a set, according to the number of sizes embraced, and these gauges were found only in a few of the largest shops. Such gauges are only for reference, from which other implements are made, hence did not meet the real want of gauges that could be given to the men for practical use. Some firms had made forged caliper gauges with round or curved contact points, but there was no manufacture of standard gauges in this country, nor was there in

England, except of pins and collars, down to 1878, as some future explanations will show.

With this much in respect to the derivation and nature of gauging implements, I will now revert to the history of their manufacture in this country, in so far as I had a part in this matter.

This is done with some diffidence, and the excuse for introducing a matter so personal in nature must be the great interest I once took in the subject, and a belief that among the few contributions I have been able to make to the advancement of constructive practice, this is by far the most important and the one I especially desire to be known, if any at all, when my work is ended.

In 1862, when foreman in the works of the Ohio Tool Co., at Columbus, Ohio, I had occasion to make some duplicate work, and not having any means of attaining standard sizes I sent to Jones & Laughlins, at Pittsburg, makers of cold rolled shafting, asking them to send a piece of 2-inch shafting that would fit the Whitworth collars they used in their rolling processes. A selected piece of this shaft, about one foot in length, two inches diameter, became a standard, from which was derived a series of sizes from one half to three inches, in the following manner:

The cross-feed screw of one of the engine lathes was measured with a rule, and found to be tolerably accurate, the pitch being eight threads per inch. A conical pin of cast iron corresponding to one end of what is called a conical testing standard shown in Fig. 1, was put in this

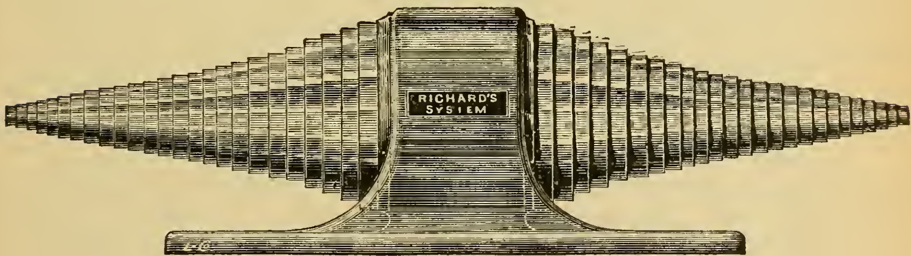

FIG. 1.

lathe and turned in steps by eighths and sixteenths of an inch, the same as in the drawing, but was left a little large. Then a finely tempered square tool was put in the lathe and its edge set true or parallel to the work. The cross-feed screw was provided with a disk divided into four parts, with a detent that would lock it at these four points. The 2-inch step on the cone was then turned, or scraped until it would caliper the same as the piece of shafting before mentioned. Then the tool was advanced a quarter or half turn and fed over the next step, and so on down to the half-inch size.

The same process was gone through from the two-inch step upward to the three-inch one. This cone was mounted in an inclined position on a cast-iron base and became a standard for sizes, resting it is true, on a very uncertain standard, but much better than no standard at all.

It was soon discovered that fixed calipers were required, and I proceeded to make these by cutting out lune-formed pieces from sheets of cast steel, also had some made from forgings of cast steel. A set of these gauges, about forty in number, was sent to Messrs. Brown & Sharpe, at Providence, R. I., to be ground to size, with flat points, and I believe were the first gauges made in this manner. Previously the points had been made curved or convex, offering only line contact to withstand wear. A set of these gauges were taken to Messrs. J. A. Fay & Co.'s works, at Cincinnati, Ohio, in 1865, and are no doubt in use there at this time.

Patents were taken out on the lune-formed, flat point calipers, and on the corrective cone, in 1867, but various circumstances prevented farther work on gauges until 1869, when I went to Philadelphia to found if possible the making of my gauges and corrective standards.

Everyone regarded the matter of such gauges as a mystery, and set small value on the audacity of a young man from Ohio, who proposed an innovation on the Whitworth system. I learned, as afterwards proved almost true, that the making of gauges was in some respects a mystery, and that no one knew how the processes were carried on, but the main impediment was that I proposed a new system.

I went into various shops to explain how pins and collars were of no use but as a reference, cost too much for common use, and were a foreign product, but no one would aid or join in such an undertaking, and I went on to England, where at the expense of a good deal of time and money, and from such information as could be gathered, the conclusion was that the means I had at command would be of no use in founding such a business, and the scheme was reluctantly abandoned until 1872. Then having more means I concluded to go on again, and rented one of the front offices in the Franklin Institute building, in Philadelphia, and arranged to have room in the basement to carry on the manufacture of gauges.

In this office were prepared the designs and detail drawings for ten special machines adapted to the various processes required in making calipers and corrective gauges. These machines, I mention with some pride. They are all in use to-day, and, in so far as I know, have not been much modified, although others of various kinds have been added.

A contract was made with Baxter D. Whitney, of Winchendon, Mass., to construct these machines, which he did with an accuracy that it would be hard to excel at this day. The work occupied about a year,

during which time I was in England, and then came the great panic of 1874, which stopped all productive industry in the way of implements of every kind. No one could conceive of what was to come; shops were closed, and skilled mechanics had to beg for their bread.

My gauge-making machines were coated with lead and tallow, boxed up carefully, stored away at Winchendon until August, 1877, when they were sent to Philadelphia, set up, and the gauge works, as we supposed, were founded, fifteen years after the first outfit of gauges was made at Columbus, Ohio, but the matter had been followed in one way or another all this time, in this country and in England.

In 1875 or 1876, Prof. John E. Sweet, at Cornell University, began and carried out there some very complete experiments in making standard calipers that deserve notice and commendation in any history of the art in this country. Some very accurate caliper gauges made at the University were exhibited at the Centennial Exhibition of 1876, with much other mechanism designed by Prof. Sweet that attracted wide attention. The first straight line steam engine, for one thing. The calipers were remarkably good examples, with broad flat points, hard and parallel, but Prof. Sweet, in talking of them, dropped a remark that became significant some years later, as will appear further on. He said: "We will not make any more of these calipers."

I will now quote briefly from a paper of mine read before the Franklin Institute, about 1878, when the various circumstances were better remembered than at this time:

"It was thought that in a month or so calipers and corrective gauges would be ready for sale, but these expectations were foiled by several circumstances, principal among which was the failure of the measuring machine, fitted with graduating screws made at the Whitworth Company's works in England, and guaranteed as to accuracy.

"This matter had before been thought of, but there was scarcely a doubt that the pitch of the screws was correct. Subsequent experiments, however, proved that not only the aggregate pitch was wrong, and the screws not parallel, but the relative pitch in so short a length as seven inches would not do to depend upon. The screws were, no doubt, as the Whitworth Company afterwards maintained, carefully made, but the delicacy of measuring tests demands more accuracy than can be attained by the pitch or movement of screws.

"The first experiment in measuring was made by preparing six rods of Stubb's wire, the points nicely finished, and the central part covered with several layers of thick soft paper to prevent induction. These rods were carefully fitted into the machine when set at six inches, temperature and other conditions being carefully observed. The rods were then uncovered and fitted into a groove cut on the side of a bar of pine

wood, and taken to Messrs. W. B. Bement & Sons' works, where a Whitworth master screw, with the necessary conveniences for testing the rods, was supplied, and even the experiments conducted by the firm, who were kind enough to take a great interest in the matter. By careful comparison it was found that the measuring machine in comparison with the screw recorded about one in ten thousand short. This, of course, stopped gauge making for the time. The test rods were then taken to London, and in three separate experiments on different standards—two by myself and one by Gen. B. C. Tilghman, member of the Institute—it was found that the rods were short, the variation being but little in the three cases, and corresponding very nearly with the less perfect experiment at Philadelphia.

"The next operation was to procure four standard test rods, from Troughton & Sims, of London, adjusted to the imperial yard of Great Britain and its divisions, by which the measuring machine in Philadelphia could be adjusted. Such rods were prepared in London with great care by those having access to the imperial standard, and my son, Mr. George Richards, then in England, brought them out to Philadelphia, and began the correction of the measuring machine, proving by combinations of the rods comparing with Whitworth gauges, and other references, but especially by combination. In the meantime another set of test rods were preparing in Manchester, England, and were forwarded to Philadelphia to prove the first set, and also the machine, which had then been tolerably well adjusted."

The adjustment of this standard machine occupied one month's time. The room was kept at one temperature, as nearly as possible, and thousands of readings were taken off, and when finally done, and the screws calibrated, the profile of error was curious to observe; the profile of one screw was convex, so to speak, and the other concave in respect to the axes.

Fig. 2 is a side elevation of this machine now in use at the works in Wilmington, Del.

I will remark here that any screw of reasonably accurate pitch can be made to measure or move for delicate measurements if its errors are translated to the reading scale, that is, if the scale or the index point on the scale, is arranged to vary with the errors of the screw. Suppose, for example, that the pitch of screw varied $\frac{1}{100}$ of an inch for each convolution, either long or short, this would make no difference if the scale from which readings were made was adjusted forward or back $\frac{1}{100}$ of an inch at the same time. This is the method of adjustment adopted for all measuring machines that were made at the Philadelphia works. The errors of the screws were compensated by the indices.

When finally we were prepared to adjust gauging implements there

arose another impediment, more formidable still. The contact points of the calipers with flat faces could not be ground parallel. The grinding wheels have to rotate parallel to these faces, and pass over them, and as the pressure is as the area in contact, the unavoidable elasticity in the wheels and their mountings, produced a curved surface. Here was an inherent principle involved—an insuperable difficulty that seemed to set at defiance all known methods of manipulation.

I remembered then Prof. Sweet's significant remark, and we applied to him for information. It was as expected. This was the difficulty he had met with. He kindly came to Philadelphia to aid us with his own experience and suggestions, but there seemed no way out of this dilemma until one day light came from an unexpected quarter.

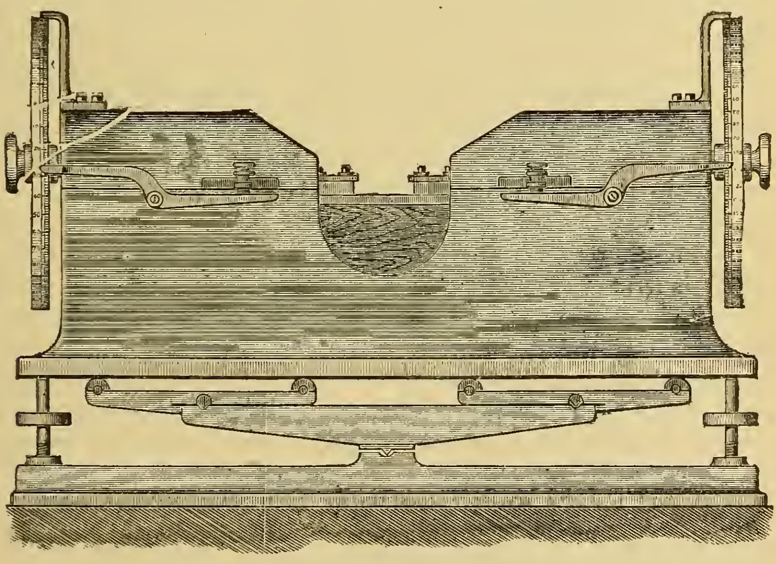

Fig. 2.

Mr. J. Morton Poole, Sr., of Messrs. Poole & Sons, Wilmington, Del., came into the works to examine the gauge-making processes. At that time I imagine that no one in the world had given so much attention to abrasive grinding as Mr. Poole. He had a laboratory for experiments and the making of grinding wheels. He had collected corundum and other abrasive minerals from all parts of the world, and had an organized and classified cabinet of such minerals. We thought then, and I believe yet, that in that laboratory was collected more knowledge of abrasive grinding material and processes than existed among all the makers of grinding wheels in this country, or in the world perhaps. Some of his grinding operations on paper calendering rollers were mar-

velous, and so intricate as to almost defy explanation. He would grind piles of these rollers eleven in height so as to exclude light between them, and the line of light, as it is called, is commonly estimated at the ten thousandth part of an inch. The guidance to produce this marvelous parallelism and truth was derived from what may be called a theoretical axis of rotation, and not from mechanical guides or ways.

Mr. Poole heard patiently an account of our dilemma, and then quietly remarked: "You must grind without pressure; come to Wilmington, and I will show you how to do this."

He had by the selection of certain fine grades of sharp corundum, and by certain methods of cementing, produced wheels that when flooded with a solvent of this cementing material would grind without pressure. I do not now remember the composition, and if I did would not feel at liberty to make it known even at this time.

The theory, as explained by Mr. Poole, was this: "A new sharp edge does not repel, on the contrary will draw the material to the edge. Now each time one of my wheels turns around a new set of edges are brought to bear, because the wheels are slowly but continually being dissolved by the liquid solution in which they run, or with which they are flooded."

The result was remarkable, and will also seem incredible. If a file was laid in front of one of these wheels, pivoted at its center so as to swing against the wheel, and a jet of the solvent solution was turned on, the file when swung against the wheel would remain there, and be ground away without any extraneous pressure whatever. This may arise from the effect produced by the liquid, or other cause than the extreme sharpness of abrasive edges. I do not claim to understand the phenomena, and we were too gratified at the results to press for explanations from Mr. Poole. He prepared wheels suitable for grinding the points of calipers, a thing he had never done before for any one, and extended many courtesies and kind acts that will never be forgotten.

The problem of making fixed calipers was solved, and gauge making rendered possible; first, by Prof. John E. Sweet, who discovered and pointed out the nature of the difficulty in grinding the contact points, and by J. Morton Poole, who removed this difficulty by his knowledge of abrasive processes, and it affords me pleasure to present these facts again, nearly twenty years after their occurrence.

As soon as accurate calipers could be ground, orders were taken and the business began, one of the first orders being for a railway works in England, and the second for the Baldwin Locomotive Works, at Philadelphia. It was sixteen years from the time of making the first set of calipers at Columbus, Ohio, and $18,000 had been spent in implements, experiments and other expense.

After the business was founded, some other firms at the East took it up, and added what Mr. Taylor called the "theatrical part." The Whitworth system of end contact or touch, as it may be called, was disparaged, and apparatus for visual divisions was instituted. So eminent a mechanic as Prof. Rogers, of Cambridge University, went so far as to forget the courtesy due to Sir Joseph Whitworth and to deride his "millionth measuring machine."

Sir Joseph Whitworth had made in his works a machine fitted with such accuracy that it would indicate movement to one millionth part of an inch, a thing easily proved and performed hundreds of times, but it was not a measuring machine in the sense of testing or defining dimensions.

I know more of this machine, which I have often seen, than it was possible for Prof. Rogers to learn then or now. It was made mainly by Mr. John Sincock, now of Birmingham, who was for many years in the works of Sir Joseph Whitworth, engaged in the gauge-making department, and who has informed me of the methods of attaining the extraordinary fitting done on this plain-looking machine.

A small bar of metal was poised like a scale beam to vibrate between the contact points of the machine. This bar was set in vibration and the points closed until the friction between them would cause the vibrations to cease. Then the pivots were drawn back, the beam set in vibration and the points returned to within one millionth of an inch of their former position and the beam again set in vibration, which would continue until the points were advanced a millionth part of an inch, when the friction would arrest vibration. The machine is in the Kensington Museum, at London, and is no doubt capable of the same demonstration now. The purpose of the machine, and its only purpose, was to show that surfaces can be so accurately fitted as not to move in stages when such minute adjustment is made.

The standard machine at the American Standard Gauge Works shown in Fig. 2, that weighs about 600 pounds, and has a range of six inches, is fully sensitive to the fifty thousandth part of an inch, as was demonstrated before the Franklin Institute in 1879, when I read the paper before referred to, illustrated by various implements and machines supplied from the gauge works in Philadelphia.

The machine is set on balance beams, a necessity discovered in its adjustment. It is covered with a close glazed case, and set where the sun will not shine upon it. This latter matter caused some difficulty during adjustment. The contact points are double, and it was discovered that during the forenoon the rear points facing southeast were loose, and front points were closer. In the afternoon they resumed their normal relation. This was caused by the sun shining through a window at the back of the machine, and is not a matter of wonder at all.

It is a common supposition that the processes of gauge-making require great dexterity and skill, because of minute dimensions dealt with, but in a gauge works there is no more care or concern respecting a ten thousandth of an inch than there is over one hundredth of an inch in common fitting. Workmen deal with these small quantities in the most common-place manner, by numerals which represent thousandths of an inch or tenths of thousandths, these being the units employed for all kinds of work.

To show that our ideas of accuracy are relative only. I once employed a wood turner from the country to turn wooden vice screws. The heads were about four inches diameter, but these began to increase because of wear in a notched piece of board he employed for calipering. He was requested to turn the heads one eighth of an inch less in diameter so that they would fit into the screw-cutting machine. He stopped his lathe, and with an appealing look said, "Mister, put that in quarters, I never come down to eighths." In evidence of this he showed us his home-made rule, that was divided only to quarters of an inch. That same man might have been taught in a week to deal with ten thousandths of an inch.

Nearly all finishing operations in gauge-making are performed by succession so as to avoid a rise or change of temperature. If calipers are to be ground, from five to twenty-five are taken at one time, and after a few passes in the grinding machines one is removed and another inserted until a close limit of accuracy is attained. Then the whole are tested by the standards. Each piece after testing is marked with chalk, 2 — 3 — 4, and so on, these figures meaning tenths of thousandths of variation from the standards. Those coming within one five thousandth of an inch were taken out as one class and the rest returned to the grinding room.

By repeated trials the accuracy would increase, and a second class within one ten thousandth of an inch would be taken out as completed. A still higher class had a limit of one twenty-five thousandth part of an inch. This was the ultimate accuracy aimed at in commercial implements. These latter were sold at a much higher price, and were seldom wanted. The expense of adjustment increases very rapidly with the precision attained, much faster indeed than the difference in price, and gauges beyond the limit of one ten thousandth of an inch were not very profitable to make.

You will no doubt wonder how such implements can be removed from a machine and be replaced again so as to have precisely the same position, but this is simple enough. Everything ground is mounted on centers or points like those of a lathe, but very carefully prepared and the center points accurate and kept clean. The centering points are cut away from the gauges.

Fig. 3 shows a common exterior or caliper gauge of the standard form.

The first use of gauging implements in a systematic way was no doubt by John G. Bodmer, at Manchester, England. Mr. Bodmer was a Swiss engineer, who, in his day, was one of the foremost mechanical engineers in Europe. He was born at Zurich, in 1786, and, when young, began his career as a millwright, that term meaning then, a constructor of all kinds of machinery. He made his way into Germany and Russia, where he held honorable commissions, and in 1833 went to Manchester, where he founded a machine works, invented and constructed nearly all kinds of machine tools known to modern practice.

I will read a short extract from a memoir of Bodmer, in the minutes of the Institution of Civil Engineers, London, dated 1868:

Mr. Bodmer approved so highly of the French metrical system of

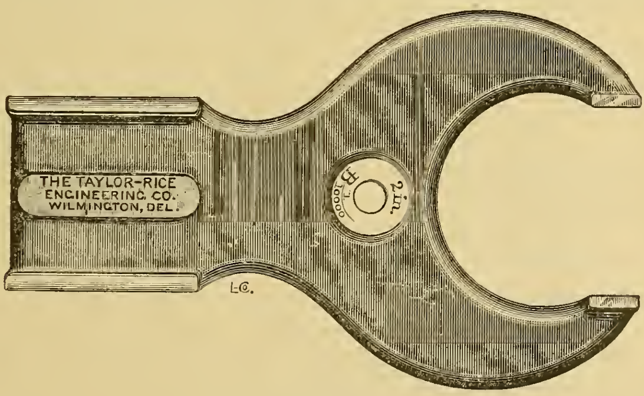

FIG. 3.

measures that he adopted it, and made use of it in all his drawings and constructions. He also, from the first, introduced it into his workshops in England; and so far from experiencing any difficulties in this matter, on the part of the men, they understood it immediately, and liked it, at least, as much as the duodecimal system represented by the old foot-rule, and the subdivision of the inch into "eighths," "sixteenths," and "thirty-seconds." A number of wooden staves of half a meter in length, accurately marked and divided, by a machine made expressly for that purpose, into decimeters, centimeters and millimeters, were distributed amongst the workmen; and although they would frequently, by way of abbreviation, call a "millimeter" a "meter," the misnomer did not lead to any errors. For the use of the pattern-makers, the measuring staves were divided so as to include an allowance for the contraction of the metal, that allowance never being left dependent upon the private judg-

ment of the men. Besides, there was in existence, and accessible to the workmen on application to the foreman, *a complete system of distinctly marked and accurately executed internal and external gauges of various kinds*, so that any required measure could be tested, either directly, or by means of the calipers, if required.

It is more than probable that Sir Joseph Whitworth's pin and collar gauges have this origin. He was then a young mechanic of Manchester, and must have known of, if he did not see, Mr. Bodmer's gauges, but such fact should not detract from the important service rendered by him to constructive mechanical and engineering processes. In all practical views of the matter he gave to the world accurate implements for machine fitting and, it may be said, accurate methods generally.

ECONOMY IN COMBUSTION AND SMOKE PREVENTION.

I. From a Chemical Point of View.

By Dr. C. F. Mabery, Member of the Civil Engineers' Club of Cleveland.

[Presented before the Club, April 14, 1896.*]

This club is so accustomed to the consideration of original thought in some form that I feel some hesitation in presenting a subject concerning which I have very little to offer that is especially original. I regret further that on account of the pressure of other duties I have not been able to consider the subject as thoroughly as would have been desirable.

In studying the prevention of smoke, it is necessary to begin with the fundamental nature of combustion. In simple terms, combustion is chemical change brought about by the union of chemical elements, with the evolution of energy, usually in the form of heat. The chemical changes, which concern combustion, are produced by the action under suitable conditions of the force known as chemical affinity. If a piece of iron is consumed in the form of rust, it combines with oxygen in a form of combustion. But the process of combustion is not observed because the operation proceeds very slowly. If the same elements were brought together so that they could unite in a short space of time, there would be more energetic action, such as we are accustomed to associate with the phenomena of combustion. Chemical affinity is a form of energy, concerning which there is much yet to be learned. The chemical elements are storehouses of great dormant energy which become sensible under the influence of chemical affinity. The earlier chemists looked upon all matter in the elemental form as containing phlogiston, a substance of negative weight, which we now indicate by the term energy.

In considering the various forms of combustion we must bear in mind the relations of the ordinary combustibles and the supporter of combustion. Ordinary combustibles include coal, wood, charcoal, natural gas, oil, coke, or turf. The supporter of combustion is the oxygen of the atmosphere. The union of other elements, however, in such a way as to unite and develop energy, may be looked upon as a phase of combustion.

The carbon compounds are the least expensive combustibles, and oxygen of the air the cheapest supporter of combustion. If hydrogen and chlorine be brought together under suitable conditions, there would be a great liberation of heat energy; but these substances are too costly to be

* Manuscript received April 29, 1896. *Secretary, Ass'n of Eng. Socs.*

used in ordinary heating operations. The greatest energy and efficiency in combustion is obtained by the union of gases, because the molecules have perfect freedom of motion, and the molecular proportions of the union may be more readily controlled.

In burning two volumes of hydrogen and one volume of oxygen we have the greatest amount of heat that can be developed in ordinary combustion, equivalent to 34,462 kilogram heat units. The molecules of these gases are free to move, and require no expenditure of energy to bring them to the point of ignition, except the small amount of heat due to their specific heats. The efficiency of natural gas as a combustible is due to the same properties, and to the fact that it is composed largely of marsh gas (CH_4). The hydrogen burns first and maintains the temperature necessary for complete combustion of the carbon. The products are water and carbonic dioxide, and the calorific power generated in its combustion is 11,063 kilogram heat units. Wood is the least efficient of the combustibles on account of the great amount of water it contains that must be converted into steam.

Coal, as we know, is composed of carbon, hydro-carbons, sulphur, nitrogen, oxygen and mineral constituents. When marsh gas burns, the hydrogen burns first; then what oxygen remains is taken by the carbon. The same is true in combustion of coal. Soft coal consists to a large extent of volatile matter. All of the hydrogen in the hydro-carbons of the volatile portions burns first; then, if there is a sufficient amount of oxygen, the carbon combined with the hydro-carbons burn ; and finally the fixed carbon. In the combustion of coal, carbon forms first carbonic oxide ($C\,O$) ; then, by further union with oxygen, carbonic dioxide ($C\,O_2$), the ultimate product of combustion. The conversion of carbon into carbonic oxide is attended by the evolution of 5,680 kilogram heat units. From carbonic oxide to carbonic dioxide the heat evolved is equivalent to 2,400 heat units. Dry wood when burned evolves on an average 3,650 heat units, and bituminous coal an average of 7,500 heat units. Anthracite coal evolves considerable more heat energy. There is greater difficulty in obtaining the same efficiency from bituminous coal than from anthracite coal, because of the way in which it burns as above mentioned. It contains such a large proportion of the volatile hydro-carbons that the distillation of those substances must be controlled within the area of combustion. If bituminous coal be fired chiefly from below, so that the air neccessary for combustion comes through the grate bars, that portion of the coal on the grate bars will be perfectly consumed ; but the portion above, being only partially heated, will be subject to a process of destructive distillation. The volatile portion will be decomposed and soot will escape. Soot, when once formed, cannot be burned economically.

Combustion in ordinary appliances is supported by draught. There must be a sufficient quantity of air introduced into the fire in order to produce complete combustion, and a sufficient excess to produce draught. This necessarily involves considerable waste of heat energy that cannot be avoided. Gases expand approximately thirty-six-hundredths of their volume for every 100° C. increase in temperature, and it is this expansion and consequent lightness that produces draught. For an adequate draught in the production of high pressure steam it is necessary to maintain a temperature equivalent to 400° to 500° F. in the flue. Unfortunately, in many forms of heating appliances, the loss of heat in the flues is greater than economy permits. Regulation of draught and flues should be such that there may not be more loss of heat than is absolutely necessary to maintain the necessary rate of combustion. As everyone knows, the most economical method of heating compartments is to place the heater within the compartment and to make a long connection to the flue. In this way the excess of heat above that required for draught will be dissipated from the connection to the flue. But where heat is to be generated for the development of power a great amount of heat energy must be produced in a limited space of time.

The fundamental principle of complete combustion is that the temperature of all the substances concerned in the change be maintained at the point of ignition. Especially the volatile portions of coal must be maintained at a sufficiently high temperature that they may be completely burned without destructive distillation. How this shall be most economically accomplished under all conditions seems as yet not to have been satisfactorily demonstrated. Many devices have been proposed. A simple method for low pressure steam consists in maintaining a brisk fire in the rear of the grate and adding coal in front where the combustion is more moderate. The products of distillation are carried forward where the temperature is sufficiently high for complete combustion. There is no difficulty in maintaining this condition, so that any grade of coal, with ordinary care, may be fired so as to give its maximum efficiency and prevent the formation of soot. This method evidently depends on faithful and efficient service in firing. Evidently it does not permit of the rapid combustion which is necessary in the production of high pressure steam.

Among the many appliances which have been suggested, the introduction of air in blast is said to effect a high efficiency. There is a stoker now in operation that claims to give an efficiency equivalent to the evaporation of 12 pounds of water for every pound of coal. I believe that anywhere from 5 to 8 pounds of water per pound of coal is considered good practice in the ordinary methods of hand firing.

Another device consists in the introduction of jets of steam. From

experiments now in progress this device seems to be efficient in preventing the formation of soot. Recently I had an opportunity of observing the operation of such an arrangement, where combustion took place on the grate bars in the ordinary way, with a draught door directly in front and jets of steam turned in upon the fuel. The temperature was sufficiently high to decompose the steam and oxidize the volatile hydrocarbon with complete combustion. There was no escape of soot whatever. The quantity of water evaporated by the application of steam in this manner, as shown by tests made by Mr. C. Goffing, was 9.5 pounds for every pound of coal. There is no doubt that the energy lost in the soot that escapes from the chimney is small. It is my impression, however, from what I saw of this application of steam, that it showed a somewhat greater efficiency than the ordinary method of hand firing, although in a test made by Mr. Goffing without steam and with air supplied solely beneath the grate, practically the same efficiency was observed.

Another essential feature in economic combustion consists in regular firing In hand firing, the temperature falls when new coal is thrown into the fire and the efficiency is impeded, especially in the frequent addition of slack coal. The various forms of stokers effect a good purpose in adding coal regularly to the fire without introducing draughts of cold air, and they render the manufacturer independent of neglect on the part of the fireman.

One of the most important problems for the consideration of the present generation is economy in the use of fuel. The great demands on our coal deposits are increasing daily, and at an enormous rate. Within the last five years we have seen the source of great energy transferred from the fields to the coal mines. In replacing the labor of 250,000 horses by electricity generated from coal, the demand for 40,000,000 bushels of grain besides the corresponding consumption of hay has ceased. Instead of generating in part the energy we expend, we have ceased to be producers and are extravagant consumers of energy that required millions of years for its accumulation; and when it is exhausted it cannot be replaced, at least in such convenient form. Ten years ago an eminent authority remarked that the coal deposits should outlast the present civilization. I wonder if he holds the same opinion to-day.

Perhaps of minor importance to the economy of combustion, but closely concerned with the comfort and convenience of those who live within reach of the soft coal belts, is the prevention of soot. Few people are aware of the expense and destruction occasioned by the immense amounts of soot turned into the atmosphere from the use of soft coal. I am informed on good authority that in one of the principal hotels in this city the soot in the atmosphere causes an actual loss

equivalent to $5,000 a year, and this is only one establishment. Do we think of the enormous amount of sulphuric acid formed by the combustion of coal which is turned into the atmosphere which we breathe? Probably 1 per cent., or 20 pounds to the ton, would be a moderate estimate of the amount of sulphur contained in ordinary coal. A bin containing 15 tons of coal contains 300 pounds of sulphur, which is equivalent to more than 900 pounds of sulphuric acid. Even such amounts in a normal atmosphere would probably not cause deleterious effect; but when the sulphuric acid escapes with soot, the soot absorbs it and it is harmful to fabrics, books, and papers.

In any manufactory true economy depends upon close control of the operation of the furnaces, but this is impossible with ordinary hand firing. An excellent means of control over combustion is obtained by connecting the smoke-stack by means of a pipe with the chemical laboratory, so that samples of the flue gases may be collected at any time for analysis. When the fireman knows that the operation of his fires is under constant supervision he will attend more closely to his duty.

When coal is cheap it requires less skill to burn it than to control combustion in obtaining the heat energy desired. In all cases the composition of the coal should be known, as well as the quantity of heat lost in the stack and the composition of the flue gases. I have been impressed by the close agreements of results that were obtained in the examinations of the composition of flue gases. Last autumn I had occasion to make an examination of flue gases from a stoker under conditions where a large excess of air was used, and it is interesting to compare these results with others recently obtained by two of our Seniors in the chemical laboratory, in the stack of a boiler where steam jets are employed. The results are as follows:

STOKER.		STEAM JETS.	
CO_2	7.00	CO_2	7.20
O	16.00	O	14.90
N	77.00	N	77.80

With the above-mentioned details in hand there should be complete control in methods of combustion, and the economy would doubtless be greatly increased. But with the present low prices of fuel, it is doubtful whether any changes relative to the prevention of soot will be possible unless made compulsory by law. It seems unfortunate that the law relating to the prevention of smoke in this city was recently pronounced of no effect.

II. From a Mechanical Standpoint.

By Prof. C. H. Benjamin, Member of the Civil Engineers' Club of Cleveland.

[Presented before the Club, April 14, 1896.*]

Prof. Benjamin.—Prof. Mabery has shown you what are the requirements for complete combustion, and it remains for me to show some of the means that have already been used to bring about that result, and also to point out some of the requirements of a good smoke preventer. Prevention is always better than cure. The only true way to treat such an evil is to prevent it.

Quite a number of experiments were made several years ago on very black, dense smoke. It was all collected and the amount of solid matter was determined by weight. It was found to be in all one-third of one per cent, or $\frac{1}{300}$ of the weight of coal burned in that time. Probably one half of this solid matter was carbon, showing that the amount of coal which is actually wasted in soot is $\frac{1}{600}$ part of the coal. This shows that there is no economy in burning smoke, as far as the manufacturer is concerned. It is his neighbor that would profit by the change.

In preventing smoke the principal requirements seem to be:—

1. That the coal shall be evenly heated.

2. That there shall be a free supply of hot air raised to the temperature of combustion.

3. That the volatile matters distilled from the coal shall pass through gases of such temperature that they shall be burned, so it shall be impossible for these gases which distill from the coal to escape by the chimney, or to become cooled after once having been ignited.

The great mistake that many manufacturers have made in trying to invent a smoke preventing device by the introduction of air about the fuel or at the bridge wall is that they have not made their air hot enough. The introduction of cold air is a disadvantage rather than an advantage, as far as preventing smoke is concerned. It will produce smoke where none existed before. There are a number of stokers on the market which, under ordinary conditions, with uniform firing by a careful fireman, will operate to prevent smoke successfully and with good economy. These different types of stokers all have a common principle, that of maintaining the thickness of the fire uniform, and of supplying the air either by means of steam jets or otherwise at a high temperature above the coal, and insuring that all the volatile matter shall pass through a hot place on the way to the chimney.

One of the more common forms of stokers consists of two inclined

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grates, all the gases being obliged to pass over the incandescent coal before escaping into the chimney, and the clinkers being deposited on the bottom.

Another type has a coking plate at the upper end, and one inclined grate running lengthwise of the boiler. Both have shaking grates.

Still another device consists of a traveling grate with an endless chain over two pulleys and a coking course at the front end, the gas passing over the incandescent coal on the way to the boiler.

There is an underfed stoker, where the coal is placed in the ash pit and forced up through the grate, this being the same as our ordinary base burner, only the other side up.

One other type is the so-called down draught furnace, which is not a mechanical stoker, in one sense of the word, but consists of a water grate connected to the bottom of the boiler by risers, at the rear usually having a drum at the connecting point, and a supplementary grate underneath on which the half burnt coal is dropped and the combustion completed. Most of the air is obliged to pass over the grate down through the fuel, a small amount of air being admitted underneath. The principle of all these is the same, that of supplying air at a high temperature and forcing the volatile matter to pass over incandescent fuel.

I presume there are other varieties that will work under ordinary circumstances with good results, and give good economy. The steam jet is applicable to all of these, and is used in many of them as a means of introducing air at a high temperature.

The great difficulty with all mechanical stokers is the fact that in many establishments there are very sudden demands for steam pressure, and there is a possibility of its being necessary to double the amount of steam used inside of fifteen minutes or a half an hour. Many stokers are not adapted to that kind of treatment. This is one reason why they have failed of adoption. A stoker can not respond so readily to a sudden demand for more steam. I will say, without prejudicing any of the other stokers, that the down draught furnace is the most successful stoker for all such emergencies. It involves the use of hand firing, the coal being fed to the grate the same as to any grate. It allows the same treatment as the ordinary open grate, and the fireman has the same liberty that he would have on any grate. In a paper read by two experts, of St. Louis, last year, it was stated that in their opinion this form of grate was best adapted to cases where there were sudden demands for large amounts of steam, and great fluctuation of the pressure and consumption of steam. They said that this form of grate had done a great deal to diminish the amount of smoke made in St. Louis, where they are more unfavorably situated than we, because they do not get as good coal.

I will mention what seems to me to be the requirements of a good smoke preventing device:—

In the first place, variable feed. It is necessary that it should be possible to vary the feed of the stoker quickly and conveniently. In the second place, it is necessary that the spacing of the grate bars should be variable; that the air spaces between the bars may be varied, and the coarseness or fineness of the grate may be quickly adapted to the particular kind of coal used. Third, it is necessary that the grate bars should be of the automatic shaking type, so as to prevent the formation of clinkers and facilitate the dropping of the ash. Some form of air control is quite important. Almost any form of stoker or grate under hard service needs a high chimney. The great difficulty in many of our establishments is that the chimney is not high enough and the draught not powerful enough. There should be a margin, and the fireman should have the means of controlling it. If there is not enough draught, the fireman can not do anything; if there is too much he can easily reduce it. It is impossible to get good results with a small grate. A grate which is large enough under ordinary conditions is not large enough under sudden emergencies. In order that a stoker may commend itself to a purchaser, it should be easily accessible for cleaning and repairing, and it should be so located that it can be taken out and replaced without tearing out the whole front of the boiler. This is one of the serious objections to several forms of stokers which otherwise are very desirable. Where the feed water is pure, the water grate is a success, and where the feed water is impure, the water grate is not a success. Among the requirements in smoke prevention no item is of such importance as good firing. A good fireman can, with an ordinary grate, give good economy, and to a large extent prevent the formation of the smoke, if the boiler is not forced beyond its capacity. A good fireman is just as necessary with any form of stoker that has ever been used. The reason why so many chimneys smoke is partly because there is not enough fireman and also because there is not enough boiler.

It has been claimed by opponents to mechanical stokers, or to any form of furnace which is intended to prevent the formation of smoke, that it is impossible to realize the full duty of a boiler when equipped with such a device. I know from my own experience that that is not true. I have made experiments with one form of stoker, and continued them for several years. I found it entirely feasible to double the rated capacity of the ordinary return tubular boiler without the formation of smoke. Of course, when the fire is being cleaned, there is a little smoke. But during ordinary combustion there is no smoke except the blue smoke, which is due to impurities. It is possible to double the ordinary rating of the boiler without smoke, with an ordinary mechanical stoker,

and to expect more than this is unreasonable. With hand firing you can not go beyond this without making smoke and without limiting the life of the boiler. It has been found by repeated experiments that such attempts are made at the expense of the boiler.

Summing up then, I will say, the principal requirements for the prevention of smoke are the adoption of a device which shall best be adapted to the particular situation ; second, a chimney of suitable size and height; third, a boiler which is at least half as big as it ought to be; and last but not least, a fireman who is worth more than $1.50 a day.

DISCUSSION.

Mr. Goffing.—I was called to The Hollenden when some of these tests were made with steam jets to determine whether the device detracted from the efficiency of the boiler, the evaporation, or the horse-power. I found that it made no material change. The evaporation and horse-power were very nearly the same. In that particular case the horse-power, with the jets off, figured from the water evaporated, was a little greater, and this was probably due to the fact that the boilers were run a little harder, and that a little more power was used that day. Probably under different conditions the same test would have shown different results. Practically no smoke was emitted when the jets were used, but the next day, when tried without the jets, there was a big volume of smoke from the chimney. As far as the other smoke burning devices are concerned, I would repeat what Prof. Benjamin just said, that with a skillful fireman much smoke can be prevented. Care must be taken to feed the coal properly, and in the proper amount, and the boiler must be such that it will not be necessary to force it beyond its capacity.

Mr. William H. Searles.—The experiments spoken of in The Hollenden Hotel remind me of some tests which I made some seven years ago at the instance of Mr. Holden, of the same hotel. A man had been permitted to put in a device for preventing smoke, which among other things used steam jets. I think he made the claim of from 25 to 30 per cent. saving of coal. The tests were made to verify his claim.

The arrangement was that for twenty-four hours continuously the furnace should be run by this inventor with his apparatus, he managing it himself, and for the next twenty-four hours I should run it without his invention. It was very carefully carried out, all of the water being very carefully measured, the coal weighed, an account of the amount of ash taken and the temperature, etc. I have not the papers with me to-night, but I recollect the result in a general way. The steam generated was used in the hotel

for mechanical purposes, they had the ordinary run of business and no special effort was made either to force the fire or to go below the usual rate. When we got through there seemed to be a very slight advantage mechanically in the device, and yet, after making an allowance for the amount of steam wasted in the jets, the two tests seemed to very nearly balance. The difference was so slight that it was felt that if the experiment were continued for a week possibly the advantage might be on the other side. The inventor's claim was not made good and the device was not adopted; history repeats itself in the recent tests by Mr. Goffing. The steam jet does prevent smoke escaping from the chimney. It does not increase the expenditure of coal, nor on the other hand does it produce any great increase of economy. There is the advantage of a clean draught. During the days of this competition when the furnace was fired without the steam jets there was some escape of smoke from the chimney, but nothing that would be considered in any sense sufficient to warrant complaint in comparison with other chimneys in the neighborhood. Careful firing, and the regulation of draught produce all the necessary steam without any great display of smoke.

Nevertheless, I am in favor of some form of mechanical stoker; these devices are a great improvement over hand-firing.

Mr. N. P. Bowler.—I have been in the business of burning coal a great many years, and I have tried a great many devices. The first device was the steam jet, we did not think it was worth keeping, and abandoned it. We have a large boiler with a small engine and a good engineer for firing. He is capable of firing so as not to make enough smoke to annoy the neighbors. He keeps the live coal back and fires in front; and being very quick in firing, very little cold air goes in under the boiler. We are in favor of a large amount of grate surface, and a large space between bars.

We have not tried any of the other stokers. We have examined them and think some are very good devices. I am in favor of using them, but my opinion is that they do not require as good a fireman as is required without a stoker. Inability to get up a high heat in a short time is true of all mechanical stokers so far as I know. Manufacturers would use automatic stokers if they would accomplish that purpose.

Mr. S. T. Wellman.—I agree with my friend Mr. Bowler that it does not take so skillful a man to fire with an automatic stoker as it does for hand firing. To obtain the best results by the latter method is, I think, one of the most skillful manual operations. Of course, in mechanical stokers the machinery must be looked after, but a man with good common sense can look after that part for a great many boilers. I think the principal cause of incomplete combustion, and of the large amount of soot coming out of our furnaces, is the fact that almost invari-

ably the boilers are not large enough for the work, and the furnace is overcrowded. In mechanical stoking you get the best results and the amount of steam required is regulated. With intermittent firing the best results can not be obtained.

Prof. Benjamin.—I would like to say a word or two more about some points in the stoker. The application of steam jets, if not overdone, I have found valuable. But there is a tendency to use too much steam. The direction of the steam jets must be very carefully looked to. If they impinge on the boiler or on the grate, there is danger of injury. I have seen instances when the fire was smoking below and the steam jets were turned on, the smoke was cut off as if cut with a knife. One great advantage of the mechanical stoker consists in the fact that if it is provided with a hopper the inrush of cold air over the grate is effectually prevented, whereas in any form of hand firing when the doors are open, if only for an instant, smoke is formed. A sudden draught of cold air is also one of the most potent means of destruction for the boiler, and is liable to make itself felt very suddenly when you least expect it.

With regard to the skill required in manipulating the stoker, it is a different kind of skill from that required in handling the shovel. It requires more mechanical ability. Another advantage of the mechanical stoker is that one man can attend to more boilers in a given time. If the stoker works as it should, I think a boy could run it. But unfortunately stokers have their ups and downs. If your coal dealer should impose upon your good nature and send you a few carloads of bad coal, you will find that you need a skillful fireman to keep your stoker in order for the next two or three days. These are the times when you need a $3 a day fireman.

Mr. Bowler.—Do you not think the use of steam jets has a good deal to do with hiding the appearance of smoke and covering up the soot?

Prof. Benjamin.—I think the action of the steam jet in the first place, is to introduce air at a high temperature where it is needed. Nearly all the devices which use steam jets have an air draught back of the jet so the air is heated by the steam and applied where it is needed to further combustion. Further than that, I believe that steam decomposes and furnishes additional oxygen where it is needed.

Mr. Oldham.—I think the great cause of smoke is want of oxygen. If I remember rightly, for every pound of coal consumed 100 cubic feet of atmospheric air is required ; 20 cubic feet of oxygen is required for the combustion of a pound of coal. Dr. Mabery said that the air should be heated, and that is the great secret of perfect combustion. A gentleman in Glasgow, whose name I can not at this moment recall, has gone thoroughly into the subject, and has brought combustion to 40 pounds per square foot of grate. Frequently this can be done without

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injury to the boiler and it is accomplished by hot air. The average combustion of coal is 16 pounds per square foot.

As regards soot accumulating, I want to show you how injurious it is. It has been found that a thin coating of soot will prevent the heating of water just as much as a $\frac{3}{8}$-inch plate placed alongside of the furnace. Soot is a serious non-conductor. Where you adopt forced draught you can increase your consumption to an unlimited extent.

I am surprised that the mechanical stokers are not more used. They were used at sea twenty years ago, and distributed the coal very evenly over the fire. I should strongly recommend the adoption of the mechanical stoker. If boilers had more diameter and more heating surface, they would find great economy in the prevention of soot accumulating on the boiler. It is almost equal to the precipitation of lime and other ingredients from water on the inside of the boiler. My advice is to adopt the best mechanical stoker, increase the size of boilers, and add air draughts.

Mr. A. H. Porter.—I would like to ask Dr. Mabery a question. Does the condition of the fire have much to do with making the steam jet a satisfactory and successful smoke consumer? Is it as efficient with a slow as with a hot fire? I ask this question because I have seen statements that water is not decomposed into its elements with a heat less intense than that of a blast furnace, while the heat in most combustion chambers is very much less intense than this; hence the water is not decomposed, but the steam is simply carried up the stack as superheated steam, and has contributed nothing chemically towards consuming the gases of the furnace, its good effect being mechanical, simply forcing the draught. Instead of adding to the heat units of the fuel, it has actually taken from them sufficient to superheat the steam itself. I remember hearing one of our former Presidents state that the smoke was simply washed or painted by the steam jet, not consumed.

Dr. Mabery.—I have had very little experience with the application of steam, except in this particular instance at The Hollenden. It seems to me that the temperature was sufficiently high for the decomposition of steam, and possibly that aided combustion. Whenever I have heard steam jets recommended, I have always thought of the possibility of a corrosion of the boiler. In ordinary combustion a small amount of sulphuric acid is formed. In the use of steam I think it forms to a greater extent. It has occurred to me that boilers might be corroded by the greater formation of sulphuric acid, but it may be a question whether or not there is a greater amount of sulphuric acid with the use of steam jets.

Mr. Balkwill.—I had occasion to observe a little point at the time this smoke consumption law was agitated. A certain engineer

referred me to the amount of water that came down in his stack and dripped out of the sheet-iron pipe connected with the brick stack. He claimed that the sheet iron was corroded by this water, which was formed by the condensation of the steam before it got out of the brick, stack. He also corroborated Professor Benjamin's statement, claiming that he used to fool the inspectors when they came around. He did not like to use the steam all of the time and provided a valve. When the inspectors came and said that smoke was coming out of his stack, he would ask them to show him where the smoke was. On the way out he would turn the handle of the valve, and there would be no sign of smoke.

Mr. Newman.—It seems to me from the experiments made at The Hollenden that the steam, instead of decomposing under the temperature, tends to deposit the carbon in a manner similar to that of passing smoke through water. It seems very probable to me that the steam would have a tendency to precipitate free carbon suspended in the combustion chamber. In my opinion hand stoking is preferable. If we take away the amount of steam used in the steam jet, the total amount of steam would be less than that obtained by hand stoking.

President Howe.—In times past I have seen large volumes of smoke coming out of the smoke stacks of the Water-works Department. Perhaps Mr. Kingsley can tell us what he has done to prevent it.

Mr. M. W. Kingsley.—If you will observe one of the chimneys, you will see that it is smokeless. We have mechanical stokers under that chimney. The other chimneys are hand fired. In the last five years we have devoted our attention to American stokers in line with smoke prevention. We have now ten boilers equipped with mechanical stokers, and are advertising for four more. As fast as the old boilers are played out, we are equipping them with new ones, and all the new boilers are equipped with smoke preventing devices.

In regard to steam jets we have tried them in times past and we have never made a success of them in our boilers. There is but little difference in the evaporation between good hand firing and mechanical stokers.

STEAM ENGINES FOR DIRECT CONNECTED ELECTRIC GENERATORS.

By E. A. Sperry, Member of the Engineers' Club of Cleveland.

[Read before the Club, May 12, 1896.*]

For the past fifteen years the subject of adapting the steam engine to the direct driving of high-speed machinery, especially of electric generators, has been one of growing importance. It was early seen that gearing and other speed-multiplying transmission of one form or another was unsatisfactory for large units, especially in lighting, and attempts were made to perfect engine designs so as to make them conform to the high-speed requirements, this seeming to be the basal proposition in the early history of this branch of the art. Later, large belt-driven units were looked upon with greater favor. In the early days of electric railroading the use of the belt-driven generator and the multiplication of smaller units were in general use. This, however, has given way to a growing preference for direct-driven generators of moderate and even low speed, with direct coupling to engines of the Corliss type, making as low as 60 and 80 turns per minute.

While this construction is found to solve many of the difficulties of the power station and to effect economies in space, efficiency, etc., it entails a heavy outlay in the cost of the manufacture of the generator itself, amounting, in many instances, to twice, or more than twice, the cost of the driving engine, even though the latter be a multi-cylinder compound condensing machine. The design of the direct-driven plant under discussion has for its object the material reduction and even halving of the first cost of the generator, which is the largest single item of expense in the installation.

Speed-multiplying power-transmission is effective in accomplishing this end, but it has its limitation, and, even in the kindred arts, it has been found to be undesirable. Within the period of which we are speaking, a change, which constitutes almost a revolution, has been worked in this branch of engineering. In nearly all the large cable stations we have seen gearing displaced by belting and rope transmission. The same thing is true of many of the mills in New England, and in all the most notable recent factory installations we have seen each line shaft, and even each tool, " direct driven."

The growing prevalence of extremely low speeds for direct driven work is considered by many to be a direct acknowledgment of the superior economies attained by the class of engines operated by valves,

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known as "Corliss." Direct acting valves are preferred by some engineers, but the Corliss valve has many followers. Owing to its cycle of operation, this valve has a serious limitation as to speed. Doubtless this can be largely increased over the present practice by the employment of aluminum at certain critical points. The inertia of at least two portions, forming essential parts of each valve, could in this way be reduced to practically one-third of its present value, and these parts, which are compelled to obey the law of falling bodies in their normal action, could thus be made to perform their functions in far less time and at a greater actual speed. In this way it has been found that the present limitation of speed of the Corliss engine—from 90 to 110—can be increased before the limits of certainty of operation is reached.

While the Corliss valve gear may be the preferred form adapted to the plant and coupling under discussion, the coupling is by no means limited to this style of valve, but is equally adapted to any of the practical and successful types of valve and valve-operating mechanism.

Turning now to the special features of the new design, its operation may be briefly indicated, by reference to the accompanying figures illustrating a 22″ x 34″-32″ stroke engine. The power arriving at the cross-head is transmitted by a short pitman to a divided lever, fulcrumed at the gudgeons seen in line with the horizontal pitman. The lever is provided with a counterweight to the right of the gudgeons and the parts of the lever are sometimes united by a bridge just above the gudgeons. The free end of this lever is connected with the pitman by a swinging link, which is about the same length as the lever, and is also preferably of divided form. At the point of union between the link and pitman a guide is provided which may work in slides, but preferably as shown upon the upright swinging arm which extends from this point down to the left side of the body of the foundation through a recess to a sole plate where it is suitably journalled. This sole plate is connected in turn with the bed plate of the engine by bolts which are clearly indicated by dotted lines. The engine is shown in the uppermost point in the stroke of its piston, and in descending swings the lever about its gudgeon to an equal angle below the pitman also indicated in dotted lines. In its descending stroke it will be seen that the pitman is given a double oscillation, to the left during the first half, and to the right during the last half of the downward stroke of the piston. These strokes are again repeated, in order, on the full upward stroke of the piston. Thus it will be seen that an entire revolution of the crank shaft requires but a single stroke of the piston rather than a double stroke as with the ordinary connection. In other words, the *speed of rotation of the crank shaft is doubled.*

If this engine piston therefore were given 110 full reciprocations

we would have 220 revolutions of the crank shaft; or if given 140, then 280 equals the crank shaft speed. This is seen to be a high velocity for an engine provided with Corliss valves, and at the same time the piston speed is kept at a comparatively low point. The upright swinging arm extending upward from the lower portion of the foundation may be utilized to operate the condenser pump and also an oil system for all the running parts of the engine. The oil naturally collecting at this lowest point in the system, the sole plate is provided with oil-retaining walls so that the pivot of the swinging arm always stands in oil.

By varying the point upon the lever by which it is attached to the cross-head, the stroke of the piston and pitman may be held on quality or may be made to vary in any desired ratio to each other. When these ratios are equal, the strength of the parts, for instance the crank shaft, pillow-block, crank-pin, pitman, etc., need not be materially altered from the best practice in the ordinary type of engine. This, it will be readily understood, would not be the case if, for instance, the piston were attached to the oscillating links at their articulating point. In this case the strokes of the pitman for anything like the best distribution of strains would have to be far less than the length of the stroke of the piston, and would therefore have to be made very much heavier for an engine of a given piston speed; furthermore, this piston speed, which is by far the greatest limitation in present engines, would in no wise be overcome, but would on the other hand be aggravated. The attachment of the piston at a point on the lever intermediate between the fulcrum and the articulating point, or any method with the arrangement shown whereby the stroke lengths of the pitman and piston may, if required, be rendered equal and allowed to vary from this point either way, I consider as one of the essential parts of the system.

The upright engine thus produced, considered generally, is of desirable form, owing to the general accessibility of the cylinder and valves from the engine room floor, requiring no stairway and gallery unless tandem construction is employed. The matter of extremely low headroom and freedom from anything resembling top-heaviness is generally conceded to be a point of advantage over the old type, and especially over the simpler forms of upright engines. Moreover, the cylinder is closer to the pillow block both in line of strain and by measurement, and the spread upon the foundation is good. While this is true, all the advantages of the upright engine, such as inexpensive foundation, low cylinder wear, etc., are retained.

Among the other points of value found to exist in the construction may be mentioned briefly the equalization of the crank strains throughout the rotation, together with the opportunity for balancing the weights of the vertical reciprocating and oscillating parts. The crank strain in

the ordinary engine is illustrated in the accompanying diagram, Fig. 4. All parts of the extension of the lever beyond or to the left of the point of attachment of the short pitman, from the cross-head, move at a greater velocity than the piston. This fact offers opportunity for power storage during the accelerating portion of the stroke or *toward* the horizontal center, for use during the last half of the stroke, or the stroke *from* the horizontal center, and the weights of the lever and link especially in this part have been so adjusted by increasing their section that practically a uniform crank effort is secured throughout the piston stroke, as indicated in diagram No. 5. The weight acting with the accelerated velocity is also valuable in lieu of fly-wheel. Owing to the high speed of the crank shaft, the fly-wheel of the engine is in any event a little less than one-half that required in the ordinary construction.

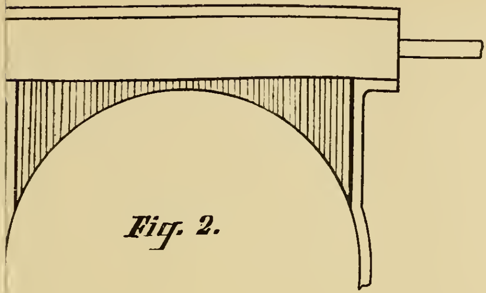
To illustrate the function of the masses and counterweights attached to and forming a part of the oscillating or reciprocating elements let us take a case of a 400 H.P. engine making one hundred double strokes of the piston and 200 revolutions of the crank shaft. The articulating-point between the lever and the link will be found to attain a velocity of about 52 feet per second crossing the center line of its oscillation, that is, in half a stroke it has attained approximately this velocity. It has been found that the weight of vibrating masses should be such that at this central point they will have absorbed in their acceleration a considerable percentage of the energy delivered from the source of power. This in most instances should vary from 30 to 50 per cent. of the power. With high velocities light parts will be found to fulfill these requirements. These percentages may be with advantage increased considerably, but should not be decreased very much below the percentages given, although experience may lead to a wider variation for special purposes.

In the case cited, one ton at this point may be made to absorb 165.6 horse-power seconds. The energy stored in the moving masses up to this point is delivered by them to the pitman and crank-shaft in the last half of the stroke. The increase in weight of the oscillating mass furthermore tends to neutralize the lunge or any tendency to pound and to give a more uniform movement while passing the center of oscillation, at which point the strains are reversed. Both these points have been found essential and necessary in the calculations, not only to smooth running but for economical construction.

Fig. 2 of the diagram indicates the new system of valve distribution for the engine. The valves are two in number instead of one. These are located in the same plane, their axes taking up an angle to each other partially embracing the cylinder for a short portion of its circumference, so that no part of either of the valves is allowed to recede

very far from the bore, giving a very material gain in cylinder clearance, as is made evident by the adjacent diagram showing the old construction.

The prime object sought in the design, viz: the reduction and practically *halving the cost of the direct driven generator*, will be found to be fully accomplished in practice. The following considerations have also been observed. The generator being only one half the size and weight of the former machines, the smaller sizes can be shipped assembled at greatly reduced cost compared with the larger units. Furthermore the reduced weight and greatly reduced number of the crossings required in the copper armature-winding and segments in the commutator give a material saving in the cost of erecting. It is hoped that the simplicity of the design and the double use of the power connection between the piston and the crank, fulfilling in this case the added function of doubling the speed, will offer a new stimulus to the two industries to which it more directly relates, and find a wider application to the art than has been the province of this paper to discuss. In addition to the direct driving of electrical generators it is now being adapted to the direct driving of fans and high-speed rolls for sheet mills, and other applications will no doubt be forthcoming.



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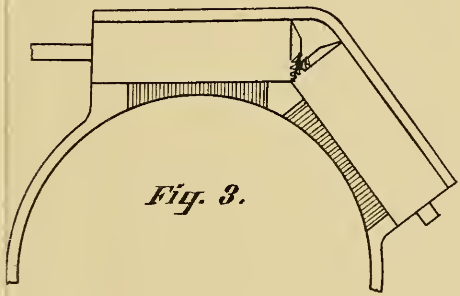

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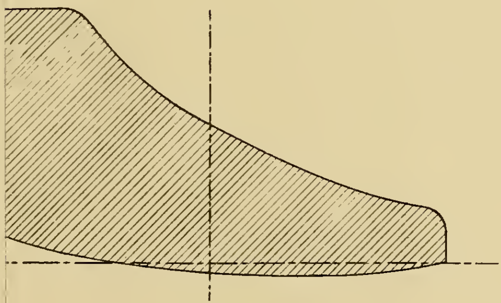

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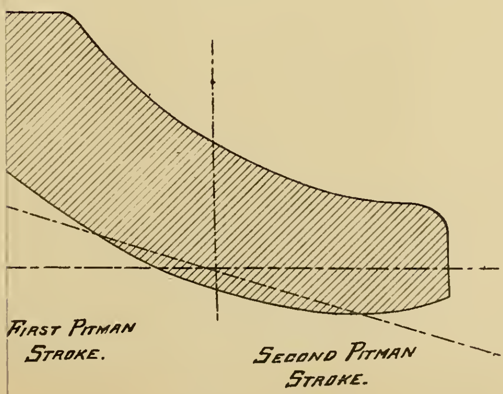

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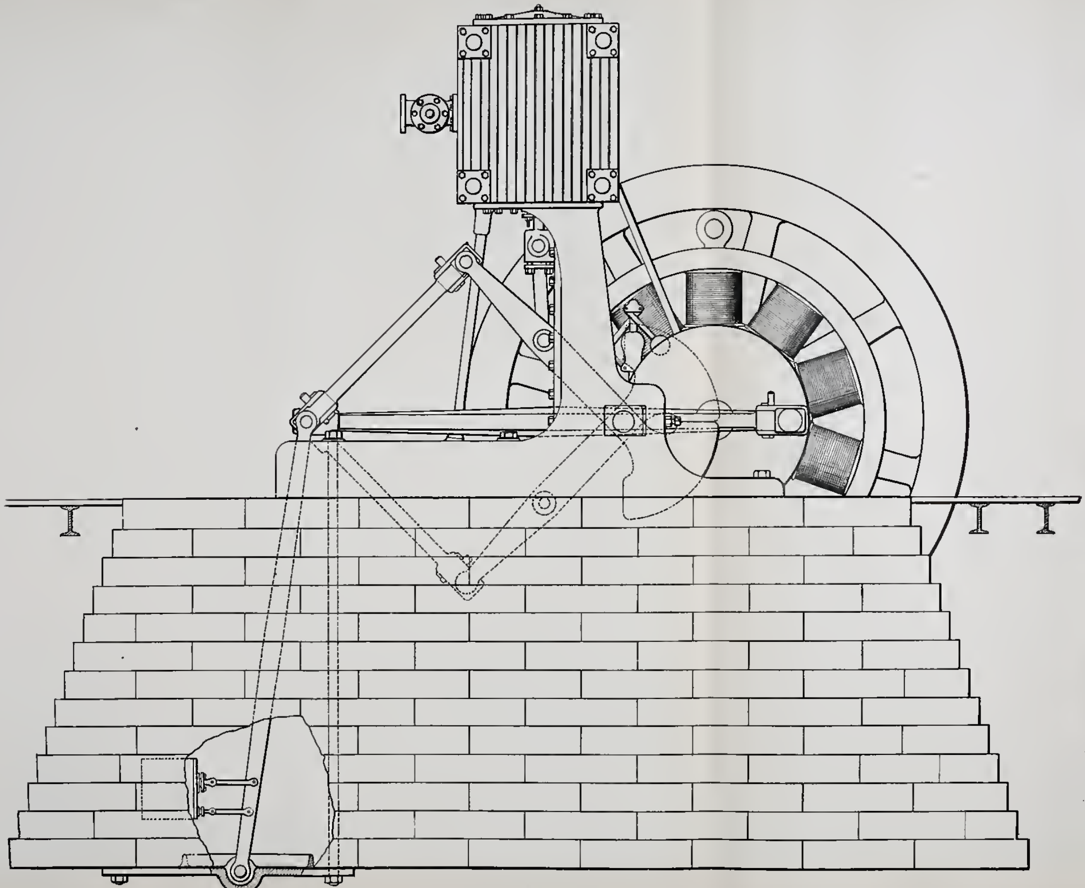

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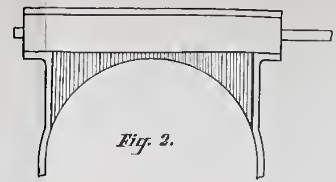

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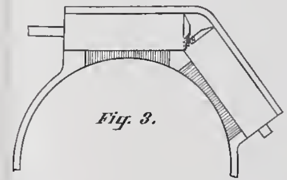

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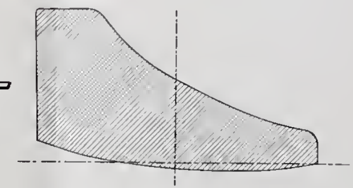

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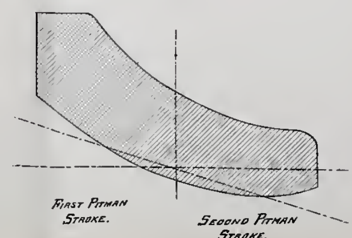

Fig. 5.

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AMERICAN HYDRAULIC GATES, WEIRS AND MOVABLE DAMS.

I. Movable Dams, Sluice and Lock Gates of the Bear-Trap Type.

BY ARCHIBALD O. POWELL, U. S. ASSISTANT ENGINEER, MEMBER OF THE CIVIL ENGINEERS' SOCIETY OF ST. PAUL.

[Read before the Society, October 7, 1895.*]

THE designing and constructing of movable dams, sluice and lock gates has heretofore been largely monopolized by government (National and State) engineers, and it is likely that lock gates and movable dams will continue in their exclusive field, but the utilization of applied electricity in the industrial arts, and the extension of large irrigation projects, by promoting the development of latent water power on the one hand, and the collection and distribution of large volumes of water on the other, will expand the opportunities of the hydraulic engineer in private practice. It is in a measure due to the limited demand, in the past, for suitable gates in private dams that their essential features have not been more widely discussed, but we may expect, in the future, in consequence of the increased number of engineers and builders interested, a development of this important detail in dam construction.

COMPETITORS OF THE BEAR-TRAP SYSTEM.

Before proceeding with a description of bear-trap gates, it may not be amiss to allude briefly to the various forms of gates and movable dams that are the competitors of the bear-trap system.

* Manuscript for this series of papers received from April 25 to May 8, 1896. —*Secretary, Ass'n of Eng. Socs.*

The good types, exclusive of lock gates,* are few and may be classified as follows:

1. Stop-planks.
2. Slide gate or door.
3. Segmental gate.
4. Drum-weir.
5. Poirée frames fitted with needles, stop-planks or doors.
6. Chanoine wickets worked from a maneuvering boat or a bridge of Poirée trestles.
7. Overhead bridge in conjunction with stop-planks, doors or needles.

The first three are sluice gates, the last three are movable dams; the drum-weir, as well as bear-traps, is adapted to either purpose.

Stop-planks were the primitive method of cutting off water, and were used vertically as flat needles in the first movable dams. The cheap and simple construction of horizontal stop planks commend them to the economical engineer. They are still in use, and for narrow openings and moderate heads, where infrequent manipulation is required, they answer the purpose as well as the more expensive constructions.

The common slide gate, or door as it is frequently termed, dates back almost as far as the stop-plank. It would naturally be the next step in the development of gates. Later, when dam building became more of a science, roller bearings were added. The increase in size of the rollers matured in the segmental gate, which may be considered as a sliding door resting on rollers of the same diameter as the hollow cylinder of which the gate is a segment. The Tainter-Parker form is the American type of this class.

Our foreign friends preceded us in the investigation of curved gates, and elaborated a number of deviations. Some of their constructions received the pressure on the concave side; the arms were tension members.

Mr. Thomas Parker, who afterwards produced the Parker improved bear-trap, was the originator of the Tainter-Parker segmental gate. Mr. Tainter purchased Mr. Parker's interest and subsequently (1886) took out a patent on the present form.

It is an excellent gate—strong, safe, reliable and inexpensive, with little liability of getting out of order. All parts are exposed for inspection. By the use of counter-weights, gates 20 feet in length and 16 feet head are handled by one man. For sluices of narrow width, designed

* The various styles of lock gates are omitted as they are not of so general an interest, and their consideration would unnecessarily lengthen this paper.

merely for the discharge of water and where the backwater does not reach to the hinge, we consider the segmental gate equal, if not superior, to all others. It is especially useful in reservoir dams.

Photographs and drawings of these gates, built by Major W. L. Marshall on the Illinois and Mississippi Canal, are published in appendix K. K., Annual Report of the Chief of Engineers, U. S. Army, 1894, and in the *Engineering News*, issue of February 14, 1895. A segmental gate, built by Majors Marshall and Davis, on the Fox River, Wisconsin, is shown opposite page 2,367, Annual Report of Chief of Engineers, Part 3, 1890.

The Poirée frames and Chanoine wickets are of French origin. They are extensively used by European engineers, and have been adopted on important works * in the United States. The conservative engineer will find in them safe and practicable designs which have been thoroughly tried and their excellent qualities demonstrated. The defects as compared with bear-trap gates are: The leakage, the labor and time consumed in operating, and the high cost. For situations where time and labor are not prime factors, the Poirée frame fitted with needles, stop-plank or doors, is satisfactory for movable dams, and the engineer that accepts it, or the Chanoine wickets, need not fear criticism. The Chanoine wickets add to the expense, but they are operated more quickly than a dam of Poirée frames. Both of these types admit of structures of any length, and leave a clear open river when the dam is down. The two systems possess three merits which will commend themselves to thoughtful and careful men: Their adaptation for any length of dam, their immunity from serious derangement by a deposit of sediment, and the facility with which damaged trestles and wickets can be replaced. The sediment in many rivers may decide the character of the dam. The two systems are favorable for a condition of much sediment. If the deposit is not too great, the parts can be loosened and raised; if deep, scraping or shoveling is at first resorted to, and afterward the erected portion utilized to deflect a current that will wash away the remaining deposit.

The overhead bridge is another European design that has been successfully introduced † into this country. Its use is restricted to moderate widths. The bridge is either a fixed or draw span, depending upon whether or not the opening is to be left clear for the passage of high-water craft. The floor of the bridge is a strong truss supporting the upper ends of needles, or posts carrying stop-plank, sliding or swinging doors.

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* Needle Dam—Big Sandy River. Chanoine Wickets—Great Kanawha and Ohio Rivers.

† St. Mary's Falls Canal, Michigan.

PLATE 1.

DRUM WEIRS

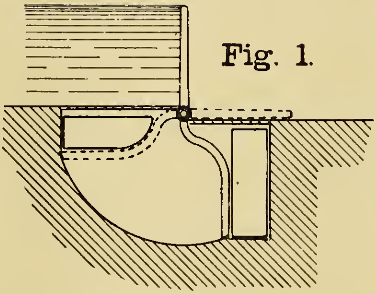


Fig. 1.

DES FONTAINE

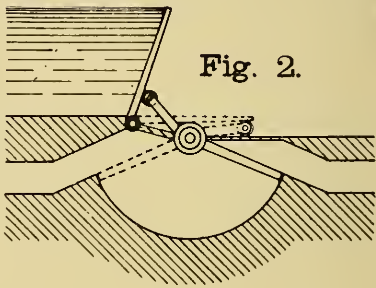
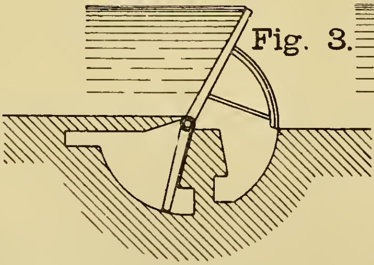


Fig. 2.

CUVINOT



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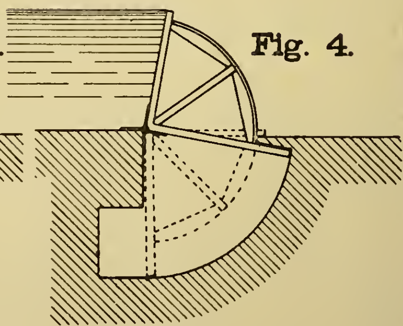

Fig. 4.

CHITTENDEN

The gates and dams thus far described are the devices of the early dam builders perfected by capable men supplied with the materials and workshops of the nineteenth century. They all require the expenditure of extraneous labor in their manipulation.

Repeated attempts have been made to utilize the velocity head of running streams and the static head of dams, to operate the gates, but thus far only two successful types have been evolved. To America belongs the credit of originating the first (bear-trap) and it perhaps stimulated M. Des Fontaines to produce his drum-weir.

The drum-weir is a neat design and theoretically has much to be admired. It has not found favor mainly because of the cost of the well and of the fear that the chamber would prove but a catch-basin for sediment.

There are four forms of this weir known to the writer. They are shown on Plate I. The first was built by the inventor on the Marne; the second was soon afterward proposed by M. Cuvinot; the third was described by Herr Nakong in 1890 *, and the last was proposed by Capt. H. M. Chittenden, Corps of Engineers, U. S. A., in 1895.

The weir is operated by the head of water. The pressure on the lower paddle is regulated by valves in flumes leading up and down stream from the chamber. In Figs. 1 and 4 the lower paddle must be the longer. The designs in Figs. 2 and 3, while more complicated, reduce the length of the lower paddles and, therefore, the depth of the well.

The drum-weir is most applicable to positions on top of fixed dams. In that situation the well is least objectionable and the liability to catch sediment a minimum. The dams erected by M. Des Fontaines are reported to work with ease and celerity.

Its advantage over the bear-trap is: the gate may be made in sections, short or long, without intervening piers; each section may be operated independent of the other; the wells are separated by water-tight partitions. With all its seeming merit and correct theoretical conception engineers may be apt to regard the drum-weir as a delicate and an expensive mechanism. Captain Chittenden's design offers the least objection and is a valuable suggestion.

The reputation of the Poirée, Chanoine and drum-weir constructions have been well earned; they deserve the encomiums expressed by their advocates. M. Malézieux characterizes them as "the three classic systems." The competitors of the bear-trap are indeed formidable and strongly intrenched in the conservative preferences of our brethren in the profession.

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* *Engineering News*, October 18, 1890.

BEAR-TRAP GATES.

We now reach the subject—bear-trap gates—the treatment of which is the purpose of this paper. We do not wish to be understood as advocating bear-traps to the exclusion of the forms just described, for we admit the limitations of each, but are confident that bear-traps are adapted to many cases, that their resurrection through the recent modified and improved forms will be permanent and that in the future they will receive due recognition in engineering literature and works.

The practice in the improvement of United States rivers has been largely borrowed from the Europeans, and it is with pride that we can discuss a meritorious gate and movable dam that is distinctly American.

HISTORY AND DESCRIPTION OF BEAR-TRAP GATES.

The early history of the bear-trap is connected with an interesting chapter in the development of our national industries and resources which we would fain recite in detail. The members of the Society, if they choose, can find lucid descriptions in the histories of Philadelphia and Pennsylvania.

The inception of the bear-trap was an incident in a remarkable enterprise by two notable men—Josiah White and Erskine Hazard. In 1814, they firmly established, by experiments in their wire mill, the value of anthracite coal. That there should have been a doubt about the feasibility of burning hard coal, or any difficulty in the process, seems at this late day quite comical. It was, nevertheless, a fact. In 1817, White and Hazard disposed of their power and plant at the Falls of the Schuylkill, and undertook the task of mining and shipping anthracite coal to Philadelphia. They acquired control of the lands of the Lehigh Coal Mine Company in the vicinity of Mauch Chunk, and obtained from the legislature, in March, 1818, authority to improve the Lehigh River. In July and October following they organized respectively the Lehigh Navigation Company and the Lehigh Coal Company.* It was necessary to create two companies, as most investors were skeptical of success in improving the river. The following graphic accounts of the improvement are quoted:

"The legislature were early aware of the importance of the navigation of the Lehigh, and in 1771 passed a law for its improvement. Subsequent laws for the same object were enacted in 1791, 1794, 1798, 1810, 1814 and 1816. A company was formed under one of them, which expended upwards of thirty thousand dollars in clearing out channels, one of which they attempted to make through the ledge of slate which ex-

*Subsequently (1822) consolidated into The Lehigh Coal and Navigation Company.

tends across the river, about seven miles above Allentown, but they found the slate too hard to pick, and too shelly to blow, and at length they considered it an insuperable obstacle to the completion of the work and relinquished it." *

White and Hazard, as managers of the Lehigh Navigation Company, commenced the successful improvement of the river in August, 1818.

"The improvement consisted, at first, of wing dams, as the company could not then raise a sufficient means for slack-water navigation, and they did not know that the market would take from them a sufficient quantity of coal to justify the expense of a more perfect system of improvement. In their report to the stockholders, December 31, 1818, the managers said that they had 'made dams amounting in length to about 13,000 feet, and supposed to contain upwards of 16,000 perches of stone. By these dams the parts of the lower section that were considered the worst have been made navigable at all seasons of common low water, and a fresh dam, 450 feet long, is nearly finished, which they trust will accommodate the public with navigation to Easton the coming season.' The following year they found that they had been misinformed in regard to the lowest point reached by the river, and that the natural flow of the Lehigh was insufficient to give 18 inches and a width of 25 feet, as was required by law, and hence they were obliged to resort to the plan of producing artificial freshets. For this purpose a peculiar sluice was needed, and Josiah White devoted himself for several weeks to the work of constructing one, finally producing what came to be known as the 'bear-trap.' He built a miniature experimental sluice in Mauch Chunk Creek, about where Concert Hall now stands, and the name 'bear-trap' was given to it by the workmen who were annoyed by the curious as to what they were making.

"During the year 1819, twelve of these dams and locks were built and the managers fully proved their ability to send to the market, by the artificial navigation, such a regular supply of coal as would supply the demand." †

Another historian says:

"The following plan was adopted to render the passage of the river more facile. The obstacles in the bed of the river were removed and thirteen dams, with sluices of various heights, were constructed of pine logs, at an average expense of three thousand dollars each. The gates of the sluice, of a peculiar construction, were invented by Mr. White (to

* History of Pennsylvania, by W. H. Egle, M.D.

† History of Lehigh and Carbon Counties, Pennsylvania, by Alfred Mathews and Austin N. Hungerford.

whom the company are indebted for many ingenious improvements) and merit particular notice. The gates in the sluice or lock were attached to the flooring by hinges and rose by the force of the water admitted from a *floom*, constructed parallel with the lock and when suspended forming a section of the dam. When the *floom* was closed, the water beneath the gates passed off, and they fell by their own weight, and the pressure of the fluid from the dams. The dam served a double purpose, forming pools of navigable water and reservoirs. At fixed periods the arks were passed with great rapidity through the sluices, and the sudden influx of water gave additional depth and velocity to the streams below."*

Some writers used the words dam, lock and sluice indiscriminately, leaving some doubt as to whether the arks of coal were sometimes locked through the dams or always sluiced over the submerged gates. President Ashbel Welch, of the American Society of Civil Engineers, in his annual address is more clear but probably mistaken in his account of the improvement of the Lehigh:

"The descending navigation they made consisted, first, in clearing the channel of rocks, and confining the water on the rapids, when low, to that narrow channel by boulder wing dams; second, when the fall was too great for this, in building dams with bear-trap locks; and third, in storing the water in pools, and letting it run only when the coal arks were running.

* * * * * * *

"Near each end of the lock was a pair of gates. . . . They could be held in any position so as to hold back the water entirely, or let it run over with more or less volume, as required. The arks containing the coal were commonly shot through over the partly raised gates as over so many dams."†

In response to a recent inquiry by the writer as to whether Mr. White built any locks with bear-trap gates, Mr. C. F. Howell, Auditor of the Lehigh Coal and Navigation Company, replied:

"I am unable to give you drawings of the lock or sluice gate known as the 'Bear-Trap.' . . . In regard to the manner of transportation of the arks of coal in the early days of the company, I find in consulting our early records that the boats were sluiced through the dams and no locks were used. Dams were constructed in the neighborhood of Mauch Chunk, in which were placed sluice gates, by means of which the water could be retained in the pool above until required for use When the dam became full, and the water had run over it long enough

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* History of Northampton, Lehigh, Monroe, Schuylkill and Carbon Counties, Pennsylvania, compiled by I. Daniel Rupp.

† *Transactions, Am. Soc. C. E.*, May, 1882, pp. 169, 170, 171.

for the river below to acquire the depth of the ordinary flow of the river, the sluice gates were let down and the boats (arks) which were lying in the pools above passed down with the artificial flow. About twelve of these dams and sluices were built in 1819."

Mr. Howell's account is the same as that given in Dr. Egle's History of Pennsylvania, where it is further stated that:

"The descending navigation by artificial freshets on the Lehigh is the first on record which was used as a permanent thing."

We cannot refrain from a more extended notice of Josiah White and Erskine Hazard—they were prominent men in their State, of high standing for sagacity and probity as well as for engineering attainments.

"Josiah White's perseverance, pluck, skill and fertility of invention, coupled with great financial ability, were the leading forces [in the operation on the Lehigh and in the coal mines]. He was the pioneer in canal development in Pennsylvania. . . . His name will be inseparably linked with the improvement of the Lehigh, with the building of important railroads, the first successful mining of coal, and its first successful use in the manufacture of iron. . . . He was a man of sterling worth and integrity."

* * * * * * *

"Erskine Hazard was scarcely second to White as a promoter of the several enterprises along the Lehigh. He was a man of great ingenuity." *

White and Hazard built the second tramway and gravity railroad (Mauch Chunk Railroad) constructed in the United States, which was the first road laid out instrumentally and with an even grade. These two men also built the first suspension bridge. †

Subsequent to the use on the Lehigh River of the bear-trap gate, it became more popular on the logging streams of Pennsylvania and in Canada, where it was used as a reservoir and sluice gate for flushing the river by an artificial wave of water on which logs and lumber were carried to market.

The old bear-trap is shown on Plate II, Fig. 1. It consists of two flat rectangular leaves of a length equal to the width of the opening in which they are placed, and having their opposite extremities hinged to the floor at right angles to the direction of the sluice way. The upstream leaf overlaps the downstream leaf. As the gate rises the upstream end of the lower leaf slides (friction is reduced by rollers) outwardly along the under surface of the upper leaf. When up full height

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* History of Lehigh and Carbon Counties, Pennsylvania, by Alfred Mathews and Austin N. Hungerford.

† History of Philadelphia by Scharf & Wescott, Vol. I, p. 584.

a cross-section of the gate is in the shape of a triangle. The total movement of the lower leaf is controlled by cleats or stay chains.

The operation of the gate is effected by the utilization of the mechanical power in the head of water. Suitable flumes are constructed under the floor or in the side piers that connect with the bodies of water above and below the dam and with the interior gate chamber. Valves in the operating flume regulate the pressure of water in the chamber. To raise the gate from a depressed position the operating flume is opened to the higher level of water and closed to the lower. The hydrostatic pressure causes the gate to rise. To depress the gate the valves are reversed, closing the operating flume to the higher level while opening it to the lower. By an adjustment of the valves the relative pressure under the leaves can be varied and the gate made to assume and retain a desired position, thus controlling the quantity of discharged water. The practice nowadays is to use a reciprocating valve or valves, which are set by an attendant in one motion. The ease with which one man can control the movement of a long bear-trap is one of its marked features.

The design did not receive from American engineers the support that it was entitled to, perhaps, because the development of our internal waterways on a large scale was not undertaken until after the French made an unfortunate construction of a bear-trap on the River Marne, and forthwith condemned it. The experience in France was widely published and served to prejudice our own engineers. It is surprising that the French should have proportioned a gate contrary to the simplest and plainest laws in hydromechanics, astonishing that we should have accepted their opinion without so much as a protest, and singular that a gate presenting so many possibilities should not have been studied. The problem is a simple one.

The effect of the Marne gate may be observed in the two quotations given below, which express the then current ideas on this style of a dam. Two distinguished American engineers reported, in 1875:—

"The fact that this system [bear-trap] has been in use in France for many years to provide artificial waves for lumbering, and yet has not been adopted on the larger rivers, is sufficient to condemn it."

An eminent English authority describing, in 1882, the Marne bear-trap, writes:—

"In order to work this weir properly by water pressure as originally intended, it would be necessary to provide a reservoir at a suitable level for ensuring the required pressure. . . . . It is improbable, therefore, that this type of weir will ever be erected again."*

* Rivers and Canals, Harcourt, p. 121.

In contrast to these views is that of Ashbel Welch, in the address quoted above. Mr. Welch said:—

"The bear-trap locks [White's on the Lehigh] have given the hint for several devices since used, and are well worthy of an examination.

"It is well worth inquiry whether these bear-trap gates would not be the best possible, and possibly the cheapest, for letting the water rapidly out of a reservoir for scouring purposes. A full stream could be set running in a few seconds, and the flow could be regulated with perfect ease and stopped at any moment. . . .

"In many rivers it is desirable to dam the stream back at low water, and let it run freely at high water. In Belgium, on the Meuse, they use needle dams for this purpose. Another probably better adjustable dam is in use in France. The bear-trap gates, with proper appliances, on a solid platform at the bottom of a river, would enable a man on shore to raise a dam across that river, or if raised, to lower it to the bottom, in a few moments.

"I have used this construction for a fish sluice in a permanent dam, by which the water ran freely through the sluice when necessary and at other times was retained at full height."

Mr. Welch's bold recognition of the bear-trap was the commencement of a revival in the United States of Mr. White's gate.

The next well-known engineers to look with favor upon the bear-trap were a board of United States officers. They recommended (1883–4) its adoption in the Beattyville dam, Kentucky River. The district engineer made the plans and in 1886 built two gates, each 60 feet long in two passes.*

We had not yet reached that point where we were willing to entirely discredit the French conclusions. Their influence was felt in the design by accepting M. De Lagrenee's assertion that "a head of two feet would be required to raise the gate," and it was concluded that the passes could not "always be closed without some auxiliary method of raising a temporary head."

Later American experiments and studies show that a more sensitive gate might have been built; nevertheless, the officer was enabled the following year to report:— "The gate worked perfectly at all stages of the water, and demonstrated the fact that the gates in both passes could be worked perfectly by one culvert in the middle of the wall, and that no further power was necessary, the pool raising the gate as it rose."†

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* Drawings shown on sheets 1, 2 and 3, opp. p. 1746, Annual Report, Chief of Engineers, U. S. A., Part 3, 1884.

† Annual Report, Chief of Engineers, U. S. A., 1887, Part 3, page 1873.

The Beattyville passes have since been replaced by a lock for other reasons than the working of a bear-trap.

In 1887, the late Col. Merrill proposed to build a drift pass, 52 feet wide, closed by a bear-trap, in the Davis Island dam, Ohio River. The pass was built in 1888–9, and has since been in constant use.

The experience on the Kentucky River led to a better proportioned design on the Ohio, and for the same reason a still better one would follow in a third construction.

During these years bear-traps were common in the mountains of Pennsylvania, but it does not appear that the builders attempted a mathematical discussion to guide them in their work. If they did, their light was hidden under a bushel, for there is no published evidence of a discussion, nor even a description of the dams.

It was about the time of the building of the drift pass in the Davis Island dam that our engineers recognized the necessity for a better understanding of the distribution of the forces on the gate. The writer recalls that in a preliminary study for a bear-trap, a board of the United States engineers, in October, 1892, directed his attention to this point which he had not fully appreciated, but caused Captain Chittenden and himself to investigate the subject, resulting in the two analyses given later on in this paper.

Mr. White's design of a bear-trap, when in an intermediate position, did not provide an even slope for the discharged water and floating bodies. To remedy the defect, if it may be termed one, Mr. John Du Bois, of Williamsport, Pa., invented, and, in 1862, patented a modification (Plate 2, Fig. 2) which is described in the Patent Office records as "A dam shoot having an apron made in sections H H', hinged together at their junction as at i, the lower section H' articulating upon a fixed hinge, and the upper end of the section H, traveling in a horizontal slot at the bottom of flume."

Mr. Du Bois' gate was soon followed (1870) in France by M. Carro's device, illustrated on Plate 2, Fig. 3.

Neither of the alterations were improvements on the prototype, but they were admissible as variations.

In 1878, one of Mr. Du Bois' gates was designed and built by James McIntyre, a contractor, in the lumber shoot of the Dells Improvement Company's dam on the Chippewa River at Eau Claire, Wis. Its dimensions were: length, 20 feet; width upstream leaf, 16 feet; width downstream leaf, 48 feet; total width when horizontal, 64 feet; rise, 7 feet. The sliding extremity of the upstream leaf was fastened to a timber the two ends of which projected 12 inches; they were rounded and moved in slots cut in the walls of the shoot. The safe passage of rafted cribs of lumber required an easy slope to the lower leaf, hence the ex-

ceptional width of the latter. The Eau Claire gate gave satisfactory service, and we have described it thus fully as it is now of historical interest in having ultimately led to the inventions of Messrs. Parker and Lang.

Two other defects in Mr. White's dam are the friction between the sliding parts and the length of base required, neither of which were improved upon by Mr. Du Bois and M. Carro. These defects were probably perceived by M. Girard, who conceived the first real improvement (Plate 2, Fig. 4). In 1868, he secured a French patent on replacing the straight downstream leaf by a folding one hinged to the floor and to the downstream end of the upper leaf. In depressing the gate, the lower leaf folded inwardly.

The writer has not learned of a reference to this last design in any publication, outside of the Patent Office records, and we assume that it has been unknown to Americans, otherwise we cannot account for the constructive idea contained therein lying dormant until revived nineteen years later, through the independent thought of an ingenious American, Thomas Parker, of Menomonie, Wis. It seems reasonable to conclude that the foreign engineers familiar with M. Girard's patent did not fully grasp its latent merits. The propositions* to apply it and Mr. White's design to lock gates after turning them on edge were to convert good lock gates into poor ones, and showed efforts as misdirected as some American suggestions.

In an attempt to improve on the old bear-trap, Hon. Felix R. Brunot, of Allegheny, Pa., patented, in 1867, a "sluice gate for dams and locks" to consist of a "hollow sluice gate furnished with valves for the admission or exit of water—so as to raise or lower the gate at pleasure." At one time, the adoption on the Ohio River of Mr. Brunot's plan was seriously considered. The engineers first proposed to combine it with a bear-trap by substituting for the solid lower leaf of the latter, Mr. Brunot's pontoon (Plate 2, Fig. 5), but later decided, provisionally, in favor of making the upper leaf a pontoon and omitting the lower one (Plate 2, Fig. 6). Subsequently the entire scheme was wisely abandoned. It was evidently the intention to change the specific gravity of the hollow leaf by alternately introducing and withdrawing water. The proposition was defective as all attempts of that kind are apt to be. The acceptable gate should respond quickly and surely to the effect alone of the available fall in the stream.

January 11, 1881, a patent was issued to Mr. Du Bois for an apron leaf attached to the free end of the upstream leaf of the common bear trap, the other end sliding on the floor below the gate (Plate 2, Fig. 7).

**Engineering News*, March 21, 1895.

The purpose sought was the same as in his patent taken out in 1862—to provide an even slope for the discharged water and floating bodies. Incidentally the apron will perform a service that may become as important as the one for which it was intended, by preventing a deposit of sediment upon the downstream leaf.

About this time, or maybe earlier, objection was urged against long bear-trap gates in consequence of their liability to warp and twist when in motion. The tendency has perhaps been overestimated and the evil effect exaggerated. The warping may have been more unsightly than hurtful. Be that as it may, the criticism was ever recurring and to prevent the twist, Mr. Du Bois proposed, in 1883, to attach a set of racks to the under side of the lower leaf and another set to the downstream end of the apron. Each set of racks engaged in a corresponding set of pinions keyed to a shaft. It was hoped that the weir could be forced to move with an even crest. More recent trials indicate that the remedy lies not in additional mechanism, but in careful construction

Besides the modifications described, many others of little or no value were patented.*

No positive advancement was made over Mr. White's pattern until 1887, when Thomas Parker received a patent for the improvement that marks an era in the development of bear-trap gates.

Before proceeding with the description of Mr. Parker's invention we will briefly state the two chief defects in the old form:

(1) Friction between the two leaves.

(2) Inability to construct a high dam upon a short base.

Friction means more head. A long base means greater cost.

Mr. Parker sought to minimize these defects. His gate (Plate 2, Fig. 8) consists essentially of three leaves hinged to each other and to the floor. The two upstream leaves fold inwardly and underneath the downstream leaf. It is M. Girard's gate turned end for end. Mr. Parker provided an upstream apron, or idler, as he called it, attached at one end loosely to the crest of the weir, the other end sliding upon the floor above the gate or upon the folding leaf. The idler, as its name implies, is no essential part of the design; the purpose is to protect the folding joint against a lodgment of chips and the like, and to provide a sheer for floating debris, roots and trees. In some situations the idler is unnecessary, but when it is used, grated apertures must be provided to admit a free circulation of water on both sides of idler.

It will be noted that we have not attributed to the French gate an influence upon the evolution of the modern bear-trap. It was to all intents and purposes, an unknown invention.

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*Wood, in 1871, Werner, in 1873, and Smith, in 1875.

In 1890, appeared the device (Plate 2, Fig. 9) of Robert A. Lang, of Eau Claire, Wis., in which he substituted chains or rods for the upper one of Parker's folding leaves and converted the idler into a functional part of the weir, but in doing so, he reïntroduced the objectionable feature of friction. For this reason some authorities deprecate the dam. Captain Chittenden, in an excellent article that appeared in the *Engineering News*, February 7, 1895, says:

"The reintroduction of sliding friction is a distinct step backward, and this is at once apparent in the results obtained from mathematical analysis. Although this analysis has not yet proceeded far enough to make possible the presentation of a full set of curves it clearly indicates that the Lang gate is inferior to the Parker in efficiency."

Other engineers contend that in the position of the gate where the friction effect is most damaging, it is overcome by the weight of that portion of the gate suspended in air; a series of practical trials will decide the question. That the friction is a factor to be considered, was evidenced in the gate built on the St. Croix River at Nevers, Wis., where it was found that the gate would not pass the critical position until after rollers were put on the free end of the idler.

The modifications of the Parker gate that were patented by R. A. Lang, might readily suggest themselves for trial to experts examining into the merits of the various designs. Major Marshall and his assistants perceived the idea and studied it before Lang published his or took out letters patent.

The reversal of the Parker gate is another instance of many minds reaching the same end. Horace Harding, United States Assistant Engineer in the Mobile district, planned a reversed Parker, minus the idler, for a lock gate in 1892; since then several have independently proposed the same change.

The following is a list of the improved bear-trap gates that have been built:

PARKER GATES.

1888. Menomonie River, Menomonie, Wis., for the Knapp Stout & Co. Company. Length, 14 feet; height, 7 feet.

1890. Milwaukee River, for the City of Milwaukee, Wis., two. Length of each, 23 feet; height, 14 feet.

1892. Muscle Shoals Canal, Tennessee, for United States Government. Length, 40 feet; height, 8.5 feet.

LANG GATES.

1889–90. St. Croix River, at Nevers, Wis., for the St. Croix Lumbermen's Dam and Boom Co., of Stillwater, Minn.:

1—Length,	80 feet;	height,	14 feet.
1	"	24 "	"	14 "
1	"	20 "	"	14 "

1891–2. Mississippi River at Little Falls, Minn., for Little Falls Water Power Co. Length, 60 feet; height, 7 feet.

1892–3. Chippewa River, at Little Falls, Wis., for Chippewa River Improvement and Log Driving Co. Length, 58 feet; height, 12 feet.

1894–5. Chippewa River, at Chippewa Falls, Wis., for Chippewa Lumber and Boom Co. Length, 80 feet; height, 6 feet.

1895. Sandy Lake Reservoir, Minn., for United States Government:
1—Length, 11 feet; height, 12 feet.
2—Length of each, 40 feet; height, 13 feet.

The two latter are both sluice and lock gates.

The untimely death of Mr. Parker interrupted the erection of his gates.

With the exception of the Sandy Lake gates, and possibly the one at the Muscle Shoals Canal, all of the above were built on low weirs and hence cannot be said to give thorough tests of their value as movable dams that must lower even with the bed of the stream. The Sandy Lake gates cannot be tried for all conditions of head until late in the spring of 1896.

Backwater, as will be explained in the analysis, has a material effect upon the operation of the improved forms, and therefore a gate erected on a weir, even if it is a low one—a raised foundation for instance,* is not worked under the conditions that obtain in a river where there is navigation in both directions.

The studies of well-known engineers during the past few years have awakened a lively interest in bear-trap gates. It is highly probable that the continued efforts will evolve a design better than those now known.

In detailing the history of the bear-trap, we have not mentioned the one proposed for the regulating works on the Chicago Drainage Canal. We do not know the plan except in a general way, and as we may be misinformed upon its details, we abstain from discussing it. We are of the opinion, however, that the engineers could have obtained a better gate in one of three standard designs—the old bear-trap, the Parker, or the Lang.

ANALYSES OF THE BEAR-TRAP GATES.

The following analyses are the joint production of Captain H. M. Chittenden and the writer. They were undertaken in 1892 in order to replace with a rational formula the rule passing current among engineers for proportioning an old bear-trap. The interest incited encouraged us to treat the Parker gate in a similar manner, which we did in 1894.

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* The crests of the Nevers gates when lowered are 7 feet above low water; the Milwaukee gates are 0.75 feet; the Menomonie, St. Croix, Chippewa and Mississippi river gates are perhaps intermediate between the first two.

At the outset the problem was confronted, of determining the profile of the water surface passing over the old bear-trap when fully depressed. A little thought showed the futility of such an attempt, and further that it would unnecessarily complicate the analysis. The expedient was hit upon, of supposing a stop-plank to be erected at the crest of the gate, or lower end of leaf X, and the water surfaces above and below level, but with a difference in elevation equal to that of the water surfaces at the inlet and exit of the operating flume. The supposition does not lead to a correct solution, but the error is on the side of safety, and so simplifies the process as to make the analysis possible and a mere question of elementary algebra. To this expedient is ascribed our success, and because of its omission by our predecessors, their failure to arrive at as good a result.

It is also assumed that the leaves are lines without thickness or weight.

With these preliminary remarks, we proceed to the

ANALYSIS OF THE OLD BEAR-TRAP.

There are two critical positions for the gate, *i. e.*, two positions where the force (head) required to produce movement must be a maximum. They are the two extremes—gate depressed and gate elevated. Therefore it is not necessary to extend the investigation beyond the two cases.

Gate Depressed.—In Plate 3, Fig. 1, X is the upstream leaf; Y the downstream, Z the lap of the upstream over the downstream leaf; Q the distance between the hinges; h'' the head caused by a stop-plank; P_1 the downward pressure; P_2 the upward pressure, and w the weight of a cubic foot of water.

$$P_1 = \frac{X \cdot Z - \frac{1}{2} Z^2 .}{X - Z} h'' \cdot w \qquad (1)$$

$$P_2 = \tfrac{1}{2} Y \cdot h'' \cdot w \qquad (2)$$

and when $P_1 = P_2$,

$$Y = \frac{2 \cdot X \cdot Z - Z^2}{X - Z} \qquad (3)$$

Equation (3) gives the relation between X, Y and Z, when $P_1 = P_2$. In practice, it is necessary that the upward pressure shall be in excess, in order to put the gate in motion and overcome friction.

Let $n \cdot P_2 = P_1$. n being a proper fraction, then

$$Y = \frac{2 \cdot X Z - Z^2}{n (X - Z)} \qquad (4)$$

and

$$Z = \tfrac{1}{2}(2 \cdot X + n \cdot Y) \pm \sqrt{\tfrac{1}{4}(2 \cdot X + n \cdot Y)^2 - n\, X \cdot Y} \qquad (5)$$

From Plate 3, Fig. 1:

$$Q = Y + X - Z = Y(1 - \tfrac{1}{2}n) \pm \sqrt{\tfrac{1}{4}(2 \cdot X + n\, Y)^2 - n \cdot X \cdot Y} \qquad (6)$$

As the value of Q does not affect the relative values of X, Y and Z, we may, for convenience, place it equal to unity; then solving equation (6) for Y and X, we have

$$Y = \frac{1 - \frac{1}{2}n}{1 - n} - \sqrt{\frac{X^2}{1 - n} + \tfrac{1}{4}\left(\frac{n}{1 - n}\right)^2} \qquad (7)$$

$$X = \sqrt{(1 - n)\, Y^2 - 2(1 - \tfrac{1}{2}n)\, Y + 1} \qquad (8)$$

For $n = 1$, *i. e.*, when upward pressure equals downward pressure,

$$Y = 1 - X^2 \qquad (9)$$

" $n = \frac{8}{10}$, *i. e.*, when upward pressure equals $1\frac{1}{4}$ times downward pressure, $Y = 3 - \sqrt{5\, X^2 + 4}$ (10)

" $n = \frac{3}{4}$, *i. e.*, when upward pressure equals $1\frac{1}{3}$ times downward pressure, $Y = 2\frac{1}{2} - \sqrt{4\, X^2 + 2\frac{1}{4}}$ (11)

" $n = \frac{2}{3}$, *i. e.*, when upward pressure equals $1\frac{1}{2}$ times downward pressure, $Y = 2 - \sqrt{3\, X^2 + 1}$ (12)

" $n = \frac{1}{2}$, *i. e.*, when upward pressure equals 2 times downward pressure, $Y = 1\frac{1}{2} - \sqrt{2\, X^2 + \frac{1}{4}}$ (13)

By supplying in equations (9) to (13) inclusive, the values of X between 0 and 1, we ascertain the corresponding values of Y; the base or distance between hinges being unity. In this manner, we drew the curves, Plate 4, showing the apexes of an infinite number of old bear-trap gates when up full height.

An inspection of the curves will show that they are quite flat near the top, and the proportion of the leaves has quite a range, even to having Y less than X, without seriously decreasing the height. In fact, in some cases, it might be preferable to sacrifice height in order to decrease the width of Y and lessen the total strain upon that leaf.

The widths of the leaves for a maximum height can be scaled from Plate 4, or can be found mathematically as follows:

Let H represent the height or perpendicular distance from the apex of gate to base; β the angle opposite leaf X.

$$\text{Cos}\,.\,\beta = \frac{Y^2 + 1 - X^2}{2 \cdot Y} = \tfrac{1}{2}n \cdot Y + (1 - \tfrac{1}{2}n) \qquad (14)$$

$$1 - \cos^2 . \beta = \sin^2 . \beta = 1 \tfrac{1}{4} n^2 \cdot Y^2 - n\,(1 - \tfrac{1}{2}\,n) \cdot Y - (1 - \tfrac{1}{2}\,n)^2 \qquad (15)$$

$$H^2 = Y^2 \sin^2 . \beta = Y^2 - \tfrac{1}{4}\,n^2 \cdot Y^4 - n\,(1 - \tfrac{1}{2}\,n)\;Y^3 - (1 - \tfrac{1}{2}\,n)\;Y^2 \qquad (16)$$

Place the first differential coefficient of equation (16) equal to O then when H is a maximum

$$Y = {}^1\!/n \cdot \sqrt{\tfrac{1}{4}\,(1 - \tfrac{1}{2}\,n)^2 + 2} - \tfrac{3}{2}\left(\frac{1 - \frac{1}{2}\,n}{n}\right) \qquad (17)$$

From equations (8), (16) and (17) we have, when H is a maximum and

for $n = 1$, $Y = .6861$; $X = .5602$; $H = .369$
" $n = \frac{8}{10}$, $Y = .6821$; $X = .5239$; $H = .333$
" $n = \frac{3}{4}$, $Y = .6811$; $X = .5144$; $H = .323$
" $n = \frac{2}{3}$, $Y = .6794$; $X = .4979$; $H = .320$
" $n = \frac{1}{2}$, $Y = .6762$; $X = .4629$; $H = .266$

Gate Elevated.—The second case we have to consider is, when the gate is raised can it be lowered?

If the interior angle between the leaves becomes 90° or less, the gate will remain up; it is important that the angle should not be less than 105° or 100°.

The curves (Plate 4) show that in no reasonable instance when $n = 1$ or $n < 1$ will the limit be reached.

The value of n in the Marne gate is 1.32; in the Beattyville gate, 1.17; and in the Davis Island gate, 0.82. There is a good reason why the French gate was defective, and if reliance can be placed upon the drawings given on Plate 35, third volume "Cours de Navigation Interieure," by H. De Lagrenée, the ill proportions were aggravated by a sill supporting the free ends of the lower leaf, which obstructed the circulation of water underneath the gate.

By our reasoning the Beattyville gate would not rise. It did rise because the side piers and the operating flume extended 105 feet above the crest. There was so much fall in the distance that the effect was to put a greater pressure under the leaves than was applied to the top side of the upstream leaf. This sort of construction, and it is a good one, when circumstances will permit, is frequently taken advantage of to insure the working of the weir.

The skeletons of the three gates show in their relation to the curves, Plate 4, that the proportions might have been improved.

The old bear-trap has been a useful and much abused gate of unique design and great possibilities, but in view of the superiority of the im-

proved forms it is unlikely that Mr. White's original design will again be resorted to, except in remote and inaccessible localities where skilled labor and metal work are difficult to obtain, and where extreme simplicity is a desideratum.

In designing one of these movable weirs, we suggest that the factor "n" should not exceed $\frac{8}{10}$ or better still $\frac{2}{3}$. The difference in height between the two is insignificant, while the resultant initial upward pressure is largely increased by the smaller value of the factor. The addition of Du Bois' apron will materially improve the working of the gate.

ANALYSIS OF THE PARKER GATE.

The process for the analysis of the Parker gate direct and reversed is the same. The analytical difference between the two forms is in the opposite direction of the forces; plus in one case becomes minus in the other. The difficulty to be overcome in a direct gate by a correct proportioning of the leaves is the final downward movement and in a reversed gate the initial upward movement.

We will suppose that the upper level of water follows the crest of the weir and that the two continue coincident.

It is observed that the ratio of the lowering to the lifting forces is least when the crest of the gate is just disappearing beneath the water; or if there is no backwater, when the gate is assuming a horizontal position. Hence, if the relative widths of the leaves are proportioned for these positions, the gate will operate in all others. See Plate 3, Fig. 2. $\overline{DG}$ = base = 1 and all other lineal measurements, fractional parts of the base. Let the nomenclature be as in the figure.

From the conditions of the problem:

$$X + Y - Z = 1 \tag{18}$$

$$Y^2 + Z^2 = 1 - 2X + X^2 + 2YZ \tag{19}$$

By geometry,

$$\operatorname{Cos}.\varphi = \frac{X^2 + 1 - (Y + Z)^2}{2X} \tag{20}$$

Combine equations (18) and (20), and solve for Z:

$$Z = \tfrac{1}{2} \cdot \left(\sqrt{1 + X^2 - 2X\cos.\varphi} - (1 - X)\right) \tag{21}$$

From equations (18) and (21):

$$Y = \tfrac{1}{2} \cdot \left(\sqrt{1 + X^2 - 2X\cos.\varphi} + (1 - X)\right) \tag{22}$$

Multiply equations (21) and (22):

$$Y \cdot Z = \tfrac{1}{2} X (1 - \cos.\varphi). \tag{23}$$

By geometry:

$$g^2 = X^2 + 1 - 2\, X \cdot \cos .\, \alpha \tag{24}$$

$$\text{Cos} .\, \theta = \frac{(Z^2 + Y^2) - g^2}{2 \cdot Z \cdot Y} \tag{25}$$

Combine equations (25), (24), (23) and (19) and solve for sin . α:

$$\sin^2 .\, \alpha = 1 - [1 - \tfrac{1}{2}\, (1 \cos .\, \varphi)\, (1 \cos .\, \theta)]^2 \tag{26}$$

Let P_1, P_2, P_3 and P_4 (Plate 3, Fig. 3) represent the forces due to the hydrostatic pressures on leaves Y and Z.

P_1 may be omitted, as it has no effect on the moment of the gate. Resolve P_3 and P_4 into two forces, P_5 and P_6, acting in the direction of Y and Z respectively. Drop P_6, as it causes only a tensile strain in leaf Y, then:

$$P_5 = \frac{P_4}{\sin \theta} - P_3 \cot .\, \theta \tag{27}$$

The forces that produce motion in the gate are P_2 and P_5.

With the center of moments around G, the equation for equilibrium is—

$$P_2 \cdot \cos .\, Y - P_5 \sin Y = 0 \tag{28}$$

substitute for P_5 its value in equation (27) and equation (28) reduces to

$$P_4 - P_3 \cdot \cos .\, \theta - P_2 \cdot \cot .\, Y \cdot \sin .\, \theta = 0. \tag{29}$$

Equation (29) is the general equation of the problem. It must be satisfied for all positions of the gate higher than that of the crest at surface of water in lower pool. If, therefore, we apply it to the critical position, *i. e.*, that position where the ratio of lowering to lifting force is least, there will be a preponderance of lowering force to depress the gate from any higher position. The equation may be treated separately for two conditions, viz.:

1. When there is no backwater, as in the case of a weir at the crest of a fall, natural or artificial.

2. When there is backwater.

1. When there is no backwater. Referring to Plate 3, Fig. 3, $M = O$, $X = Z$, and the forces are

$$P_2 = \tfrac{1}{6}\, h''' \cdot Z \tag{30}$$

$$P_3 = \tfrac{1}{3}\, h''' \cdot Z \tag{31}$$

$$P_4 = \tfrac{1}{2}\, h''' \cdot Y + \tfrac{1}{6}\, h' \cdot Y \tag{32}$$

Substitute in equation (29) the above values of P_2, P_3 and P_4,

$$\left(\frac{h'}{h'''} + 1\right) Y + 2\,(Y - Z \cdot \cos \theta) - Z \cdot \sin \theta \cdot \cot .\, Y = 0. \tag{33}$$

When the gate is assuming a horizontal position, $\frac{h'}{h'''} + 1 = \frac{0}{0} + 1$ and $\sin\theta \cdot \cot Y = 0 \cdot \infty$.

After being evaluated,* the two indeterminate expressions reduce to

$$\frac{h'}{h'''} + 1 = \frac{1 - X}{\sqrt{\frac{1}{2}(1 - \cos\varphi)} - Z} \qquad (40)$$

and

$$\sin\theta \cdot \cot Y = \frac{1 - X}{Y - \sqrt{\frac{1}{2}(1 - \cos\varphi)}} \qquad (43)$$

With the aid of equations (18), (40) and (43), and $\cos\theta = 1$, equation (33) can be reduced to

$$(1 - \cos.\varphi) - \sqrt{\tfrac{1}{2}(1 - \cos.\varphi)} \cdot (Y + Z) - (1 - X)^2 = 0 \qquad (44)$$

For $Y + Z$, substitute its value as found by adding together equations (21) and (22), and reduce equation (44) to

$$(1 - X)^3 - 2\,\tfrac{1}{2}(1 - \cos\varphi) \cdot (1 - X) + (1 - \cos.\varphi)^2 = 0 \qquad (45)$$

Equation (45) can be solved for X by trials. Angle φ is fixed by

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* To evaluate $\frac{h'}{h'''} = \frac{0}{0}$, proceed thus (Plate 3, Fig. 4):

$$\sin\beta = \sin(A - B) = \frac{1}{g^2}\left[X\sin\alpha\,(Y - Z \cdot \sin\theta.) - Z \cdot \sin\theta\,(1 - X\cos\alpha)\right] \qquad (34)$$

$$\cos\beta = \cos(A - B) = \frac{1}{g^2}\left[(1 - X\cos\alpha)(Y - Z\cos\theta) + X\sin\alpha \cdot Z \cdot \sin\theta\right] \qquad (35)$$

$$\frac{h'}{h'''} = \frac{Y \cdot \sin\beta}{Z \cdot \sin(\theta - \beta)} = \frac{X \cdot Y \cdot \frac{\sin\alpha}{\sin\theta} - Y \cdot Z}{Y \cdot Z - X \cdot Z\frac{\sin\alpha}{\sin\theta}} \quad \text{for } \alpha = 0 \text{ and } \theta = 0 \qquad (36)$$

To evaluate $\frac{\sin\alpha}{\sin\theta} = \frac{0}{0}$ (equation 36), square the expression and from equation (26) we have

$$\frac{\sin^2\alpha}{\sin^2\theta} = \frac{1 - \left[1 - \frac{1}{2}(1 - \cos\varphi)(1 - \cos\theta)\right]^2}{\sin^2\theta} \qquad (37)$$

The first differential coefficient of numerator and denominator of right-hand member of equation (37) is

$$-2\,\frac{\left\{1 - \frac{1}{2}(1 - \cos\varphi)(1 - \cos\theta)\left[-\frac{1}{2}(1 - \cos\varphi)\right]\sin\theta\right\}}{2 \cdot \sin\theta \cdot \cos\theta}$$

Cancel $\sin\theta$, then when $\theta = 0$, above expression becomes $\frac{1}{2}(1 - \cos\varphi)$, or

$$\left.\frac{\sin\alpha}{\sin\theta}\right]_{0,\,0} = \sqrt{\tfrac{1}{2}(1 - \cos\varphi)} \qquad (38)$$

the slope leaf X shall take when gate is raised full height. Y and Z can be obtained from equation (21) or (22), and (18).

For the condition of absolutely no backwater, *i. e.*, when the backwater does not reach to the base of the gate, equations (45), (21) or (22), and (18) give the proportions for a gate that will lower for any height of water in the upper pool.

2. When there is backwater.

Inasmuch as the most difficult position, with backwater as a condition, for the gate to pass in its downward motion, is when the crest approaches to a level with the surface of water in the lower pool, we may take the expression for the forces from a position of the gate where the hinge E is submerged, then

$$P_2 = \tfrac{1}{2} h'' \cdot M + \tfrac{1}{6} h'' \cdot \frac{N^2}{Z} \tag{46}$$

$$P_3 = \tfrac{1}{2} h'' \cdot Z - \tfrac{1}{6} h'' \cdot \frac{N^2}{Z} \tag{47}$$

$$P_4 = \tfrac{1}{2} h'' \cdot Y. \tag{48}$$

Substitute in equation (29) the above values of P_2, P_3 and P_4,

$$\tfrac{1}{2} h'' Y - \left(\tfrac{1}{2} h'' Z - \tfrac{1}{6} h'' \frac{N^2}{Z} \right) \cos. \quad \theta - \tfrac{1}{2} h'' \cdot M + \tfrac{1}{6} h'' \frac{N^2}{Z} \cdot \sin \theta \cdot \cot. \quad \Upsilon = 0 \tag{49}$$

Introduce equation (38) in equation (36), we have

$$\left. \frac{h'}{h'''} \right]_{0,0} + 1 = \frac{(Y - Z)\, X \cdot \sqrt{\tfrac{1}{2}(1 - \cos \varphi)}}{Y \cdot Z - X \cdot Z \cdot \sqrt{\tfrac{1}{2}(1 - \cos \varphi)}} \tag{39}$$

Substitute in above, equations (18) and (23), and reduce

$$\left. \frac{h'}{h'''} \right]_{0,0} + 1 = \frac{1 - X}{\sqrt{\tfrac{1}{2}(1 - \cos \varphi)} - Z} \tag{40}$$

To evaluate $\sin \theta \cdot \cot \Upsilon = 0 \cdot \infty$, proceed thus (Plate 3, Fig 5)

$$\begin{aligned} \sin \theta \cdot \cot \Upsilon &= \sin \theta \, \frac{\cos \Upsilon}{\sin \Upsilon} \\ &= \sin \theta \, \frac{\cos (V + W)}{\sin (V + W)} \\ &= \frac{Y \cdot \sin a \, . \sin^2 \theta - (\cos a - X)\,(Z - Y \cos \theta) \sin \theta}{(\cos a - X)\, Y + (Z - Y \cos \theta) \dfrac{\sin a}{\sin \theta}} \end{aligned} \tag{41}$$

For $a = 0$ and $\theta = 0$, equation (41) reduces to

$$\sin \theta]_0 \cdot \cot \Upsilon]_0 = \frac{1 - X}{Y - \dfrac{\sin a}{\sin \theta}} \tag{42}$$

Substitute for $\dfrac{\sin a}{\sin \theta}$ its value, as given in equation (38), then equation (42) becomes

$$\sin \theta]_0 \cdot \cot \Upsilon]_0 = \frac{1 - X}{Y - \sqrt{\tfrac{1}{2}(1 - \cos \varphi)}} \tag{43}$$

When the gate is just disappearing beneath the backwater, $M = Z$, $N = O$, and $h'' = O$.

Equation (49) now reduces to

$$Y - Z \cdot \cos.\ \theta - Z \cdot \sin.\ \theta \cdot \cot.\ Y = O. \qquad (50)$$

In place of $\sin.\ \theta \cdot \cot.\ Y$ insert its value as given in equation (41) and also make the following substitutions:

From equation (1),

$$Y = 1 - X + Z \therefore Y - Z \cdot \cos.\ \theta = (1 - X) + Z(1 - \cos.\ \theta)$$

From equation (1),

$$Z = -(1 - X) + Y \therefore Z - Y \cos.\ \theta = -[(1 - X) - Y \cdot (1 - \cos.\ \theta)]$$

From equation (1), $Y - Z = 1 - X$.

From equation (23), $Y \cdot Z = \frac{1}{2} X (1 - \cos.\ \varphi)$,

From equations (25), (24), (23) and (19),

$$(1 - \cos.\ \theta)(1 - \cos.\ \varphi) = 2(1 - \cos.\ \alpha). \qquad (51)$$

From trigonometry,

$$\sin.\ \theta \cdot \cos.\ \alpha - \sin.\ \alpha \cdot \cos.\ \theta = \sin.\ (\theta - \alpha)$$

then equation (50) will reduce to

$$(1 - X)\frac{2 \sin.\ (\theta - \alpha) - X \cdot \sin.\ \theta}{2(1 - \cos.\ \alpha)} - X^2 \sin.\ \theta + X \sin.\ (\theta - \alpha) = O. \qquad (52)$$

$$\text{and } X = \frac{\sin.\ (\theta - \alpha)}{\sin.\ \theta} \qquad (53)$$

Angle α is known from the equation:

$$\sin \alpha = \frac{h}{H} \sin \varphi$$

and angle θ is known from equation (51):

$$\cos \theta = 1 - \frac{2(1 - \cos .\ \alpha)}{(1 - \cos .\ \varphi} \qquad (54)$$

Equation (53) gives value of X for any desired angle of φ. Y and Z can be obtained from equations (21) or (22), and (18). Equation (53) is solved by trials, after first fixing upon the values of φ and $\frac{h}{H}$.

For the condition of backwater there is a limiting case, *i. e.*, when the backwater is infinitesimal, and when the crest of the gate is at the same elevation. $\alpha = 0$ and $\theta = 0$.

To derive the value of X for the limiting case, resume equation (53):

$$X = \frac{\sin .\ (\theta - \alpha)}{\sin .\ \theta} \qquad (53)$$

$$X = \cos . \alpha - \frac{\sin \alpha}{\sin \theta} . \cos . \theta. \qquad (55)$$

For $\alpha = 0$ and $\theta = 0$, equation (55) reduces to

$$X = 1 - \left.\frac{\sin . \alpha}{\sin . \theta}\right]_{0,0} \qquad (56)$$

Introduce equation (38) into equation (56), then the latter becomes

$$X = 1 - \sqrt{\tfrac{1}{2} (1 - \cos . \varphi)}$$

SUMMARY OF EQUATION FOR FINDING WIDTHS OF X, Y AND Z.

Depending upon the height of backwater, X is found from one of the three following equations:

1. When there is no backwater,

$$(1 - X)^3 - 2\tfrac{1}{2} (1 - \cos . \varphi) (1 - X) + (1 - \cos . \varphi)^2 = 0 \qquad (45)$$

2. When there is backwater.

(*a*) When the height of backwater has a finite value:

$$\begin{cases} X = \dfrac{\sin . (\theta - \alpha)}{\sin \theta} & (53) \\ \sin . \alpha = \dfrac{h}{H} . \sin . \varphi & \\ \cos . \theta = 1 - \dfrac{2 (1 - \cos . \alpha)}{(1 - \cos . \varphi)} & (54) \end{cases}$$

(*b*) When the height of backwater is infinitesimal,

$$X = 1 - \sqrt{\tfrac{1}{2} (1 - \cos . \varphi)} \qquad (57)$$

Y and Z are found from either of the two following sets of equations, X being known,

$$\begin{cases} Y = \tfrac{1}{2} \left(\sqrt{1 + X^2 - 2 X \cos . \varphi} + (1 - X)\right) & (22) \\ Z = X + Y - 1 & (18) \end{cases}$$

$$\begin{cases} Z = \tfrac{1}{2} \left(\sqrt{1 + X^2 - 2 X \cos . \varphi} - (1 - X)\right) & (21) \\ Y = 1 + Z - X & (18) \end{cases}$$

From the above formulæ we have prepared the following:

TABLE OF PARKER GATE PROPORTIONS.

φ	No backwater.				$\frac{h}{H}=0.8$				$\frac{h}{H}=0.6$			
	X	Y	Z	H	X	Y	Z	H	X	Y	Z	H
10°	.994	.090	.084	.173								
20°	.975	.185	.160	.333								
30°	.946	.280	.226	.473					.855	.322	.177	.427
40°	.905	.376	.281	.582	.968	.353	.321	.622	.784	.430	.214	.504
50°	.854	.470	.324	.654	.896	.456	.352	.686	.702	.533	.235	.537
60°	.793	.560	.353	.687	.800	.558	.358	.693	.615	.630	.245	.533
70°	.724	.645	.369	.680	.677	.660	.337	.636	.524	.716	.240	.492
80°	.649	.722	.371	.639	.542	.754	.296	.534	.432	.793	.225	.425
90°	.568	.791	.359	.568	.437	.827	.264	.437	.350	.854	.204	.350

φ	$\frac{h}{H}=0.4$				$\frac{h}{H}=0.2$				$\frac{h}{H}=$ limit.			
	X	Y	Z	H	X	Y	Z	H	X	Y	Z	H
10°									.9129	.137	.050	.159
20°									.8264	.267	.093	.283
30°	.782	.362	.144	.391	.748	.383	.131	.374	.7412	.388	.128	.370
40°	.704	.471	.175	.453	.666	.492	.158	.428	.6580	.497	.155	.423
50°	.622	.572	.194	.476	.587	.590	.177	.450	.5773	.59	.173	.442
60°	.538	.664	.202	.466	.509	.678	.187	.441	.5000	.683	.183	.433
70°	.458	.744	.202	.430	.433	.755	.188	.407	.4264	.758	.185	.400
80°	.386	.810	.196	.380	.362	.820	.182	.357	.3572	.822	.179	.352
90°	.322	.864	.186	.322	.302	.871	.173	.302	.2929	.874	.167	.293

We have platted on Plate 5, the curves formed by the apexes of an infinite number of Parker gates for the six conditions of "no backwater" and for $\frac{h}{H} = 0.8$, 0.6, 0.4, 0.2, and limit. On the same base are shown, in outline, the gates built in the Milwaukee River and Muscle Shoals Canal. The relation of the two skeletons to the curves indicates that the gates are not correctly proportioned, being too high for their base. The theory is substantiated by the fact that in both instances the gate cannot be completely lowered by the hydrostatic pressures alone. On the crests of each of the 23 feet long Milwaukee gates, the builder placed 7,500 pounds of iron. The added weight called for a larger initial raising force, which was fortunately available. The head was obtained, as in the case of the Beattyville dam, in the fall from inlet of operating flume to gate. Both incidents prove how "circumstances alter cases," and the opportunity an engineer has to exercise judgment.

In the foregoing analysis we did not introduce a factor corresponding to n in the old bear-trap, because in practice it is not convenient to build the gate in a manner that will reduce γ and θ to zero, as would be necessary in order to equilibriate the forces in a depressed gate. In the analysis, $n = 1$; but in actual construction $n < 1$.

Our discussion for the condition of backwater has been criticised by an engineer who contends that the limiting equation alone is applicable. We assumed in the case where $\frac{h}{H}$ has a finite value, that after the crest of the gate is submerged the weight of the released water on leaf X is sufficient to bring it to a horizontal position. We believe we are justified in the assumption because a slope in the water surface between the ends of the operating flume is a prerequisite for the erection of a bear-trap, and because the slope from the crest of the gate to the lower end of the flume can be utilized in depressing the gate.

In this treatment of the Parker gate, we have referred throughout to one built with the folding leaf upstream. The remarks are equally applicable to a gate in a reversed position except that the terms would have been given an opposite meaning.

On Plate 6, Fig. 4, we have drawn a reversed Parker proportioned by the formula for any height of backwater $\left(\frac{h}{H} = \text{limit}\right)$, and $H = 12$ feet. The procedure we follow in laying out a Parker reversed is to place horizontally a line equal to X connecting hinges G and F. (Plate 6, Fig. 1.) Draw another horizontal line ED equal to Y; D being placed at a horizontal distance from G equal to the theoretical base $(X + Y - Z)$. The line ED must be sufficiently below $G - F'$ to prevent the Z-leaf and X-leaf from touching each other except at the hinge F'. A precaution can be taken by inserting a few blocks between the two leaves to maintain a divergence between them. The Z-leaf will be a trifle longer than the figure given in formula and table, but the increased length is more than compensated for by the values of γ and θ, which are a minimum in the positions given. After the gate is fully drawn, allow it to sag until the line GF (top of X-leaf) is horizontal. (Plate 6, Fig. 4.) In this position the gate is fully depressed and should be supported by blocks.

We do not particularly admire the manner of connecting the idler, in Figs. 1 and 4, but it permits building the gate with full dimensions and provides a narrow foot-bridge. Two other connections are shown in Figs. 2 and 3, which both destroy a part of the effective range of the gate. The raised crest in Fig. 3 should be avoided.

We have been impressed with the desirability of a smooth and even surface over a depressed gate and the avoidance of projections against which drift may catch, or a depression that will collect sediment.

The same care must be exercised in raising a reversed Parker as in an old bear-trap, so as not to allow the strain to be suddenly applied to the chains.

LANG GATE.

It would have been a pleasure to submit in this paper the results of an analysis of the Lang gate, but we have not had the time to accomplish it. Our investigations demonstrated that the formulæ are difficult, if not impossible, of reduction to the simplicity of the Parker formulæ, and that the final result can only be arrived at through a long and tedious series of trials and approximations.

If any members of the society wish an exercise in mathematics, we commend to them the Lang gate problem. The hydrostatic forces P_2, P_3, P_4 and P_5 (Plate 3, Fig. 6) that tend to produce motion, and friction, P_6, can be assembled at the crest in the three forces P_7, P_8 and P_9, and a formula obtained. It is tolerably well settled that the critical position is in the downward movement when angle θ is approximately 90°, and if while the gate is in this position the backwater reaches above hinge E, the combination of the conditions are most unfavorable for the movement of the gate.

If it should be established that the Lang design is theoretically (omitting friction) as good as the Parker, it may be found that the limiting proportions of the former do not materially differ from those of the latter.

In the absence of a true guide, we suggest to engineers building Lang gates in backwater, not to exceed the Parker dimensions for $\frac{h}{H} =$ limit. Without backwater, the restrictions imposed by the idler ($X +$ idler $=$ base) restricts the height to less than the Parker form.

It is unnecessary for us to enter into a more detailed description of the Lang gate, as it will be fully dealt with in papers to be read before the Society by members and resident engineers.

HEAD REQUIRED TO OPERATE BEAR-TRAP GATES.

Considerable speculation has been indulged in as to the minimum head that will insure the successful operation of bear-trap gates.

There is only one working-dam on record about which specific information is given. U. S. Assistant Engineer William Martin, in local charge of the Davis Island Dam, reported:

"There is but 12 inches reduction in the head when the gate is down, and the resistance to the gate rising being largely increased by the velocity of the water passing through the chute, makes the downward force greater than the lifting power. As a matter of fact, when

necessity requires the bear-trap to be lowered under full head for the purpose of passing drift or otherwise, the pool has to be drawn off 6 inches below the normal level before the gate can be raised again."*

But the specific gravity of the leaves, the size of the operating flume, amount of leakage and pressure that can be maintained in the interior chamber, are not stated. There may be causes other than the proportions of the gate that prevents rising under the conditions cited by Mr. Martin. The same engineer has pointed out that the addition of a Du Bois apron would facilitate the movement of the gate.

We will take this opportunity of emphasizing the necessity for a large operating flume. The question should not be: How small can the flume be made? but: How large can the flume be made without entailing too much expense in the construction and too much power to manipulate the valves?

It is unfortunate that none of the improved bear-traps have heretofore been situated where direct observations could be made. The record of an old style gate is not a guide to the requirements of the more sensitive improved forms. Theoretically, the slightest head will produce motion in the gate, but practically, allowance must be made for friction, excess in weight of gate, effect of foreign matter wedging in the space between the leaves and walls of the sluiceway, sediment, faults in construction and the dynamic effect of swiftly passing water, all of which will take power to overcome.

Pending the publication of trustworthy data derived from experience, an engineer may be taking chances in building a bear-trap of a specific gravity approximately equal to 1, without having available a fall of 6 inches between the inlet and outlet of the operating flume.

APPLICATION OF BEAR-TRAP GATES.

Bear-traps are applicable—

First—To sluices and drift passes. Their adaptability to these purposes is too obvious to need reiteration.

Second—To locks. Engineers and inventors long since recognized the utility of automatic gates in lock construction, and have striven to perfect a device that would meet all objections. Bear-traps were early suggested and have been more persistently advanced since the development of the improved forms.

The proposed manner of working bear-trap lock gates was clearly presented in 1884, by a board of U. S. Engineers, in these words:

"The usual type of bear-trap gate operates very well in a chute where there is a difference of level on the two sides of the gate; but

*Annual Report, Chief of Engineers, U. S. A., 1892, Part 3, page 1982.

when a pair of bear-trap gates is used, as in a lock, each gate must either be raised or lowered in still water. If the gates are made buoyant they will not sink, and if heavier than water they cannot be raised unless power can be brought to bear. It is possible to obviate these difficulties in this way:

"Let the upper gate be made buoyant; it will then remain up and act as a gate in still water. If now the space underneath the gate be connected with the lower pool by a culvert, the pressure of the upper pool will keep the gate down, and thus the gate can be maneuvered under either condition. For the lower gate the conditions must be reversed. It must be made heavier than water, and can only be raised by bringing the head of the upper pool under it by means of culvert in the side walls."

The operation appears feasible, and for the lower gate is effective. The lifting of the upper gate in still water is dependent upon the buoyancy of the leaves, which at best is a limited force of such small power that the gate might not respond quickly and surely. The use of air chambers to increase the buoyancy is a doubtful expedient. The lower gate can readily be made heavy enough to sink with all desired speed.

It is unlikely that bear-traps will displace the common miter-gates in locks of moderate width, but the former are well suited to the lower gates in wide locks. For a long upper lock gate we look towards another design—possibly upon the lines of the Chittenden drum weir—a heavily weighted gate raised to an erect position by the hydrostatic pressure.

When bear-traps are used, the locks may be filled and emptied by discharging and releasing water over the crests of the gates instead of through culverts. The rapidity of the operation will be governed by the velocity of the current in the lock chamber.

Third—To movable dams. We might well add, to movable dams in some situations or in connection with other types.

We imagine that some of the questions which an engineer would consider before adopting a bear-trap, are:

(1) Will a sufficient head of water be available to move the dam? If not, can a fall be gained, as high water recedes, by arranging the dam in sections, the foundations of which form a series of steps? Can a fall be created by a low auxiliary movable dam above a portion of the main dam, or by raising a part of the dam built of needles or wickets?

(2) What is the character of the sediment carried by the river; is it coarse, or fine and penetrating like Missouri river mud?

(3) To what extent is sediment liable to be deposited upon the dam?

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*Annual Report, Chief of Engineers, U. S. A., 1885, Part 3, pages 1863–4.

PLATE 2.

BEAR TRAP GATES

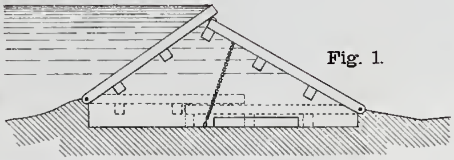


Fig. 1.

OLD BEAR TRAP
DAVIS ISLAND DAM, OHIO RIVER

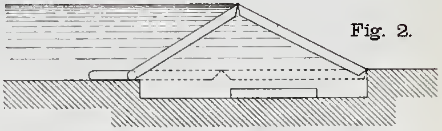


Fig. 2.

DU BOIS' MODIFICATION

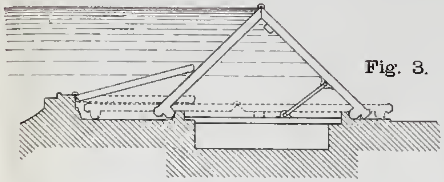


Fig. 3.

CARRO'S MODIFICATION

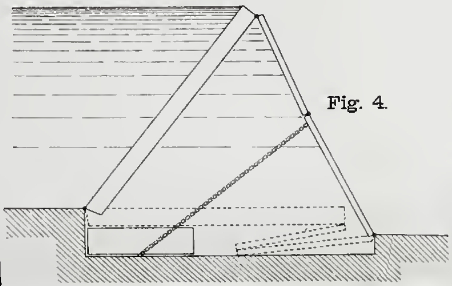


Fig. 4.

GIRARD'S PATENT, 1868

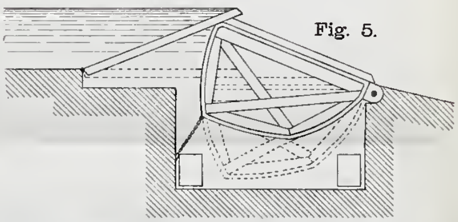


Fig. 5.

BRUNOT'S GATE WITH UP-STREAM APRON

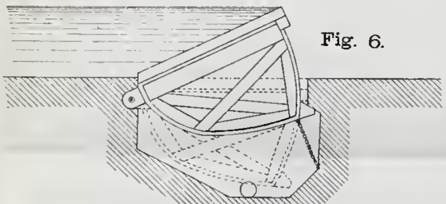


Fig. 6.

BRUNOT'S GATE

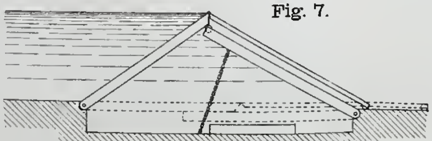


Fig. 7.

OLD BEAR TRAP
WITH DU BOIS' APRON

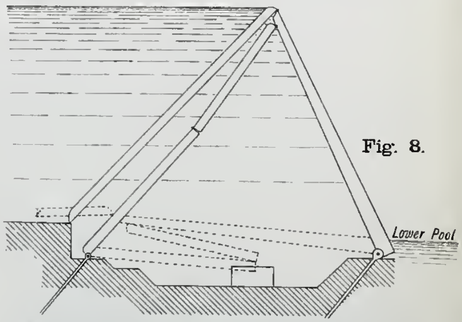


Fig. 8.

PARKER'S IMPROVED BEAR TRAP
MILWAUKEE RIVER DAM, WIS.

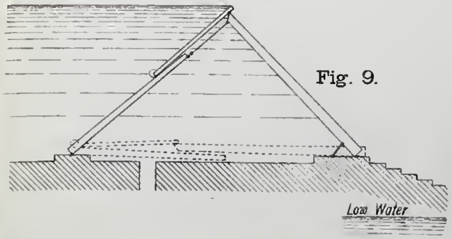


Fig. 9.

LANG'S IMPROVED BEAR TRAP
NEVER'S DAM, ST. CROIX R. WIS.

PLATE 3.

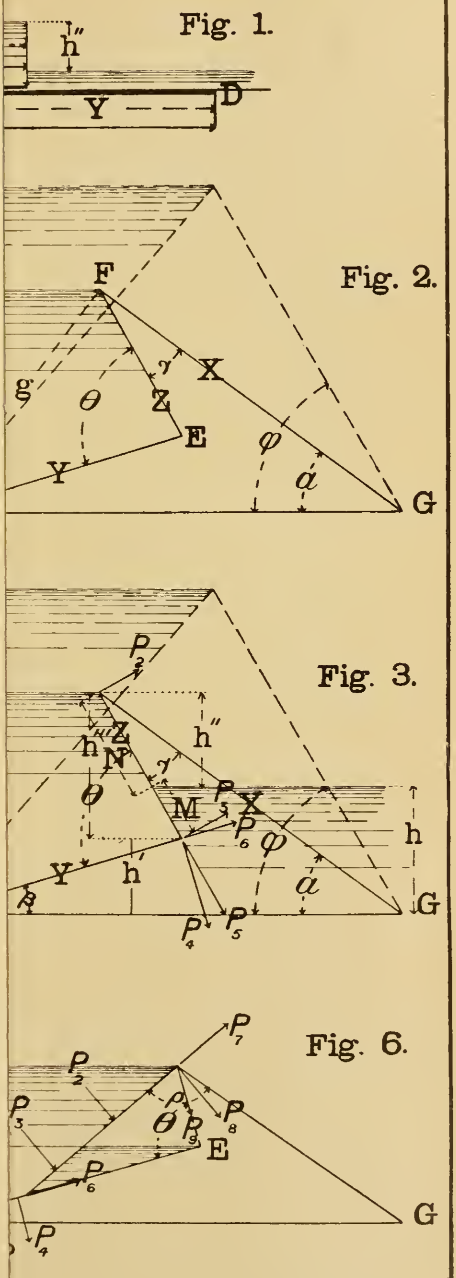


Fig. 1.
h''
Y
D
Fig. 2.
F
g
θ
γ
Z
X
E
φ
Y
α
G
Fig. 3.
P_2
h''
h'''
Z
N
γ
θ
M
P_3
X
P_6
φ
h
Y
h'
α
β
G
P_4
P_5
Fig. 6.
P_7
P_2
ρ
P_3
θ
P_9
P_8
E
P_6
G
P_4

PLATE 3.

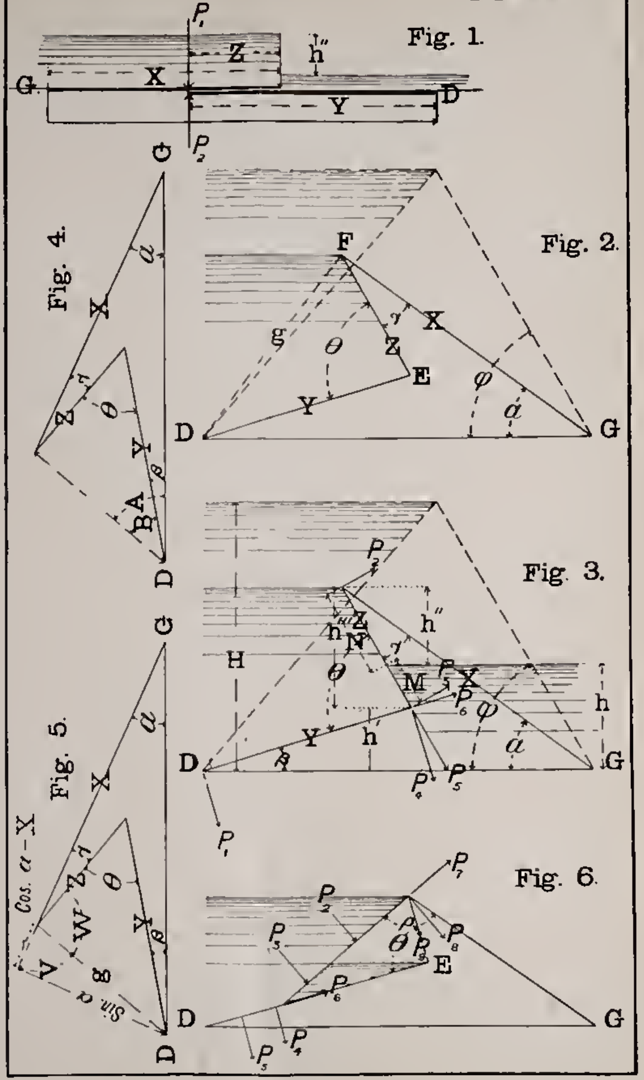


PLATE 4

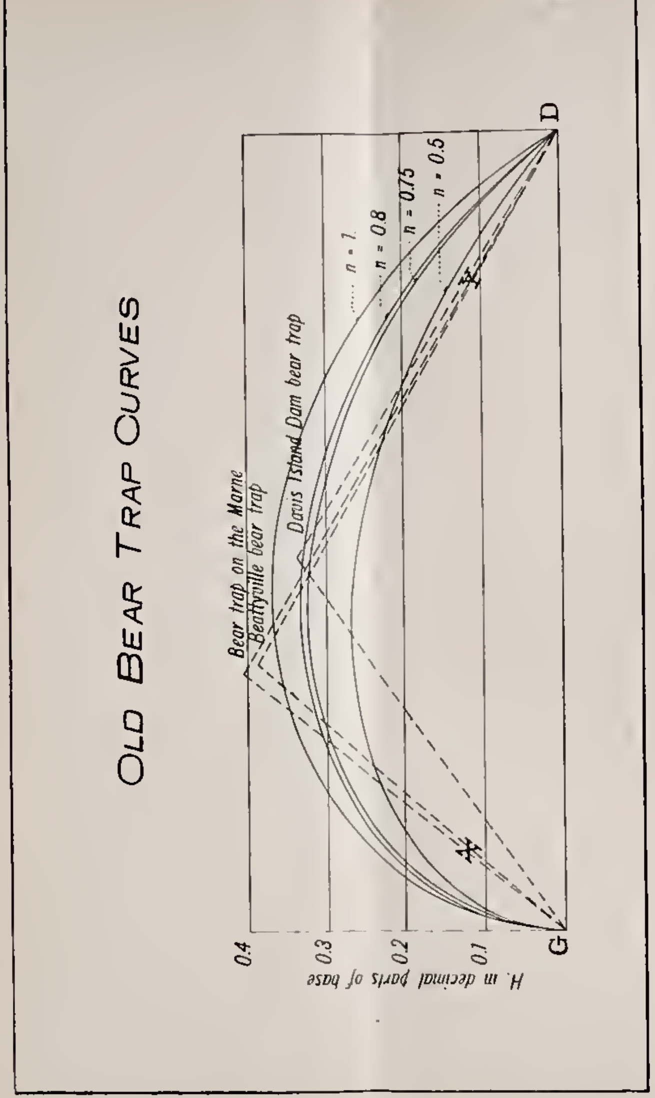
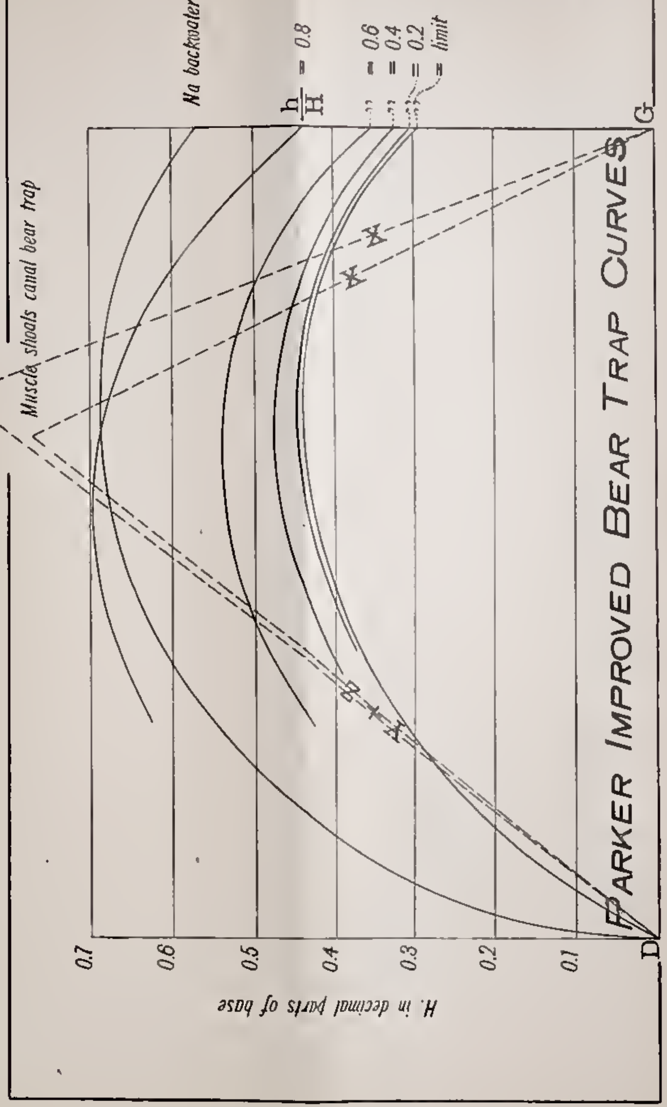
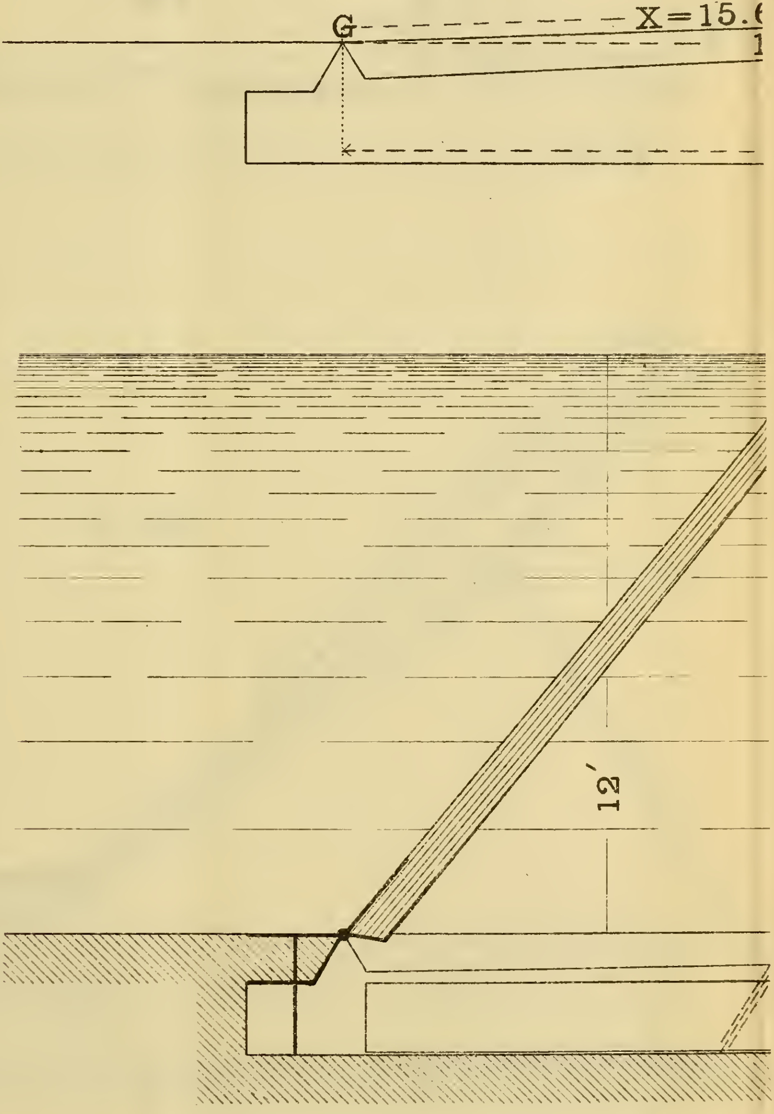


PLATE 5





PARKER'S IMPROV

Proportioned

PLATE 6

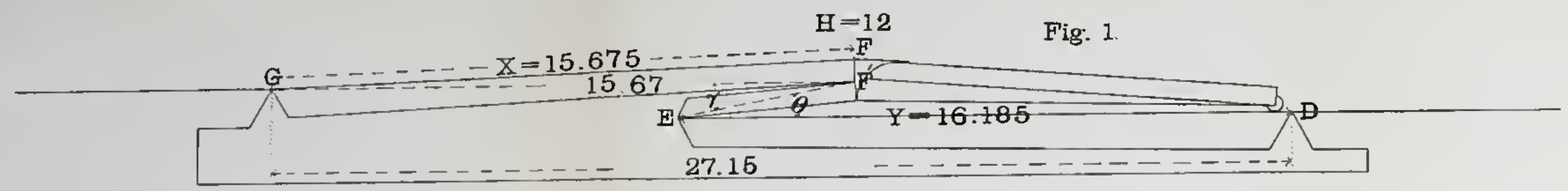


Fig. 1.

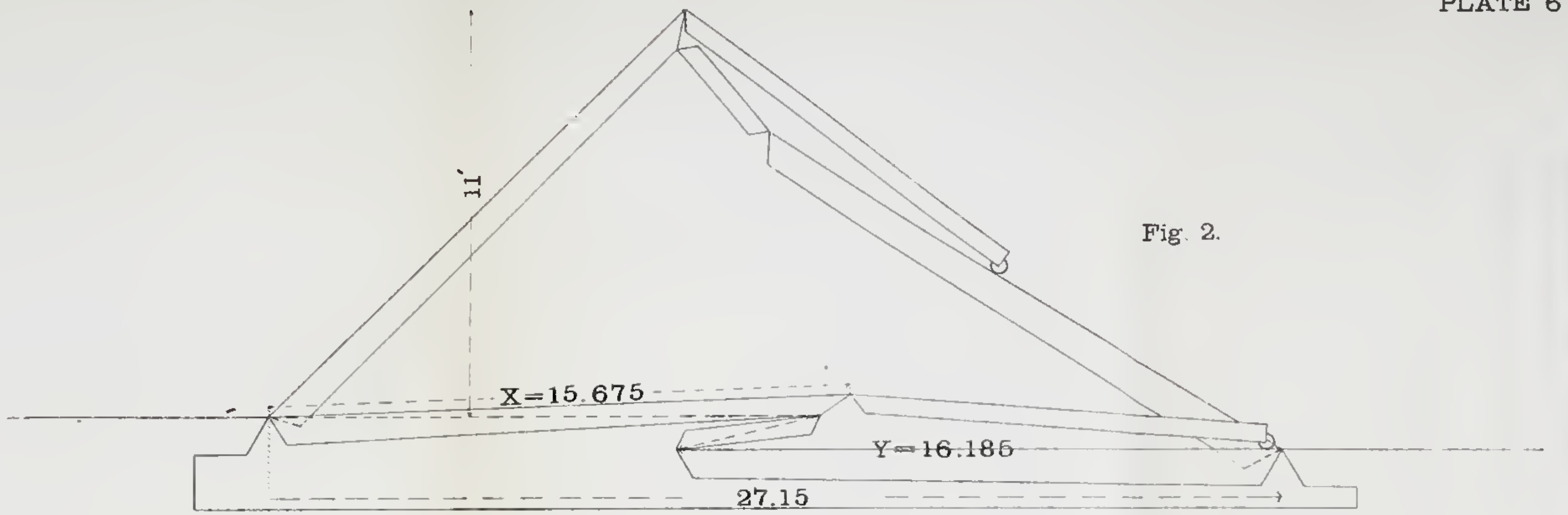


Fig. 2.

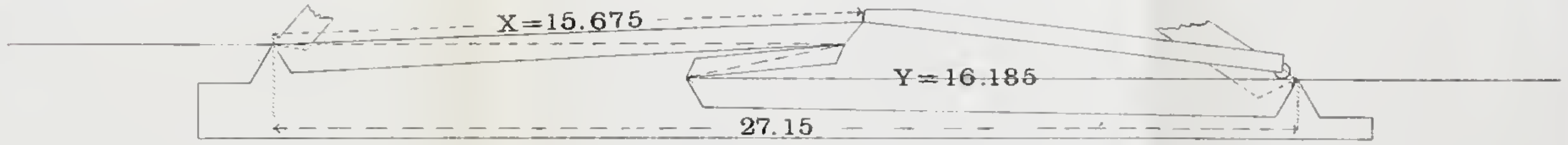


Fig. 3.

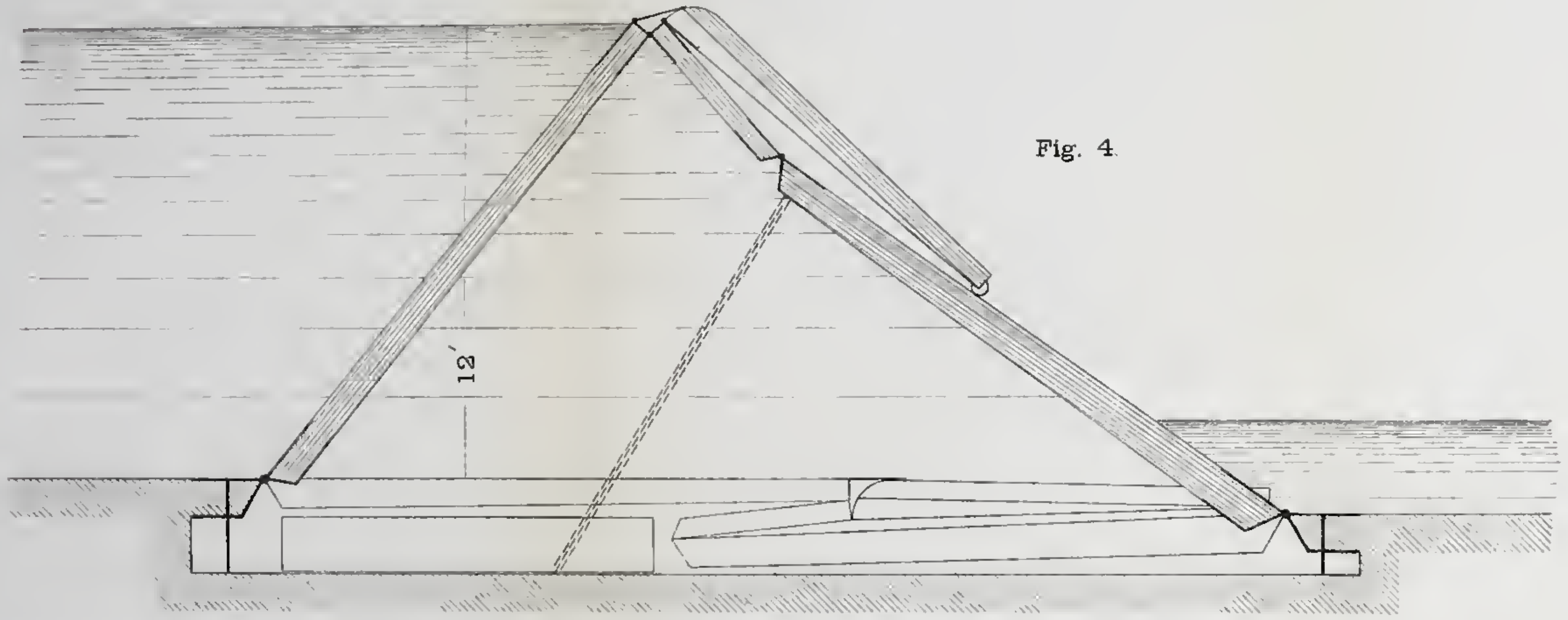
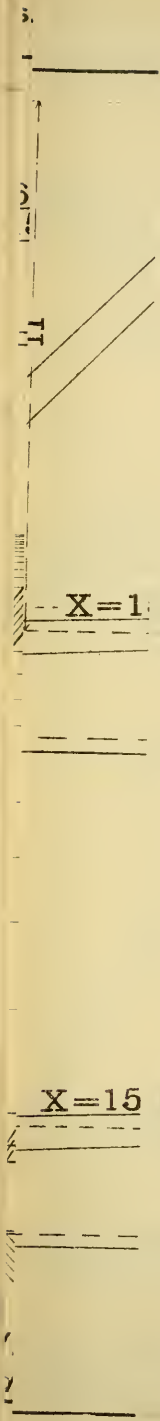


Fig. 4.

PARKER'S IMPROVED BEAR TRAP GATE REVERSED

Proportioned for all heights of backwater.


X=1
X=15

The questions are pertinent and must be satisfactorily answered, or a bear-trap is out of the question.

An important matter in this connection is the length that it is practicable to build a bear-trap. There are now two gates (Lang pattern) in operation, 80 feet long, each, and one (old style) was built on the Monongahela River by Du Bois, 120 feet long. There is no doubt that these lengths can be considerably increased, but the maximum will probably be reached gradually.

CHOICE OF BEAR-TRAP GATES.

For minor structures in remote localities the old bear-trap need not be ignored. In important works, the Parker, Lang, or some future improvement will supersede the prototype.

Generally speaking, we should say that in masonry dams, where the bed of the sluice is elevated above the lower pool, and where the width of foundation must be curtailed, the Parker is the best publicly known form. In wooden constructions, and in all dams where backwater is met, the choice between the Parker and Lang is not so well defined. Each have advantages that will appeal in a different degree to the hydraulic engineer. For lock gates, the Parker has two distinct merits: the efficiency (ratio of height to base), and the tight chambers formed by the three leaves, the base and walls of the lock, admitting the introduction of the full pressure without separating the parts of the gate. The analysis of the Parker has no bearing upon the design for a lock gate. It is possible to build one that in an erected cross-section would be a right-angled triangle, with an efficiency of 1, but a preference may be given to the form of an equilateral triangle with an efficiency of .866.

As between the Parker direct and reversed, there is but a slight difference in their relative value as lock gates. In sluices and movable dams the direct or reversed is better when the larger part of the fall is below or above the gate, respectively.

The reversed Parker presents a clean and smooth surface for the passage of drift, ice and sediment.

CONCLUSION.

In our effort to curtail the length of this paper we have omitted a reference to many minor details, and have not fully discussed some of the major ones.

Our purpose will be subserved, if we succeed in interesting members of the society in the subject and in provoking a general discussion on the merits of the system.

We are not prepared to state that the best form has been realized. Much may be expected from the continued and intelligent efforts of professional workers.

II. Bear-Trap Gate in Davis Island Dam, Ohio River.

By Wm. Martin, U. S. Assistant Engineer.

The subject of improvement of our waterways has in the last few years become one of unusual interest, not only to the engineer, but also to the industrial classes, by whom it is being taken up as a question involving their existence in the race of competition in trade. In the improvement of the Ohio River at Davis Island Chanoine Dam, with which I am more directly connected, the most practicable type of dam for use on this river has been discussed for a number of years, and with a view of determining the question a number of the Chanoine wickets were removed and a section of bear trap 52 feet long and 9.33 feet high was built in the year 1890, as represented on Plate 2, Fig. 1, of Mr. Powell's paper. This dam has fulfilled the object of its builder, viz: the passage of driftwood, which caused a great deal of annoyance in the practical working of the dam, by becoming entangled in the wickets. The bear-trap facilitated the removal of the large drift by the rapidity with which it could be disposed of. This dam was not properly proportioned for working under the maximum head, which occurs when the river is at its lowest stage. Under the greatest head with which the dam has been operated, the gate will not rise, and this necessitates drawing off the pool six inches, before the dam can be put up. We are now hinging a short apron to the upper leaf 7 feet wide—lapping over the lower leaf in a similar manner to the Parker gate reversed, Plate 6, Fig. 4, of Mr. Powell's paper. This, we believe, will relieve the difficulty we have experienced. On rivers like the Ohio, which carry such large quantities of drift, and in which floods occur at times so rapidly that it becomes impracticable to operate movable dams like the Chanoine, on account of the drift clogging the structure, and making it impossible to lower in time, there should be adopted a type of dam that can be maneuvered under all conditions and stages of water. The simplest form of quick-acting dams that have been tested by experience is the old style bear-trap. The bear-trap dam at Davis Island has filling and discharging conduits in each pier, supplying and discharging the water from both ends of the dam. This arrangement prevents the warping of the gates, but I believe that in a dam of great length this action would still occur notwithstanding that the water was supplied and discharged from each end. Some device to cause the gates to rise uniformly has been the need in all the bear-trap dams that have come under my observation. A good example of this twisting action was seen in the dam built by Mr. Du Bois in Dam No. 1, Monongahela River, referred

to in Mr. Powell's paper. This dam was 120 feet long and about 9 feet high, with the filling and discharging culverts in one pier only. The warpage was so great that in raising the dam, the end next the filling culvert came up about 5 feet in advance of the opposite end, and again in lowering, the same side was in advance the same amount, making a variation of 10 feet in the crest. This amount of twisting action would destroy the structure in a very short time. While this action in a small degree would not be injurious in a properly built structure, it is unsightly in appearance, and should not exist if it can be prevented. How can this be prevented? There are several ways in which it can be accomplished.

1st. By building the dam so tight that the leakage will be reduced to a minimum, and the water thus admitted slowly, distributing the pressure uniformly beneath the gate.

2d. A conduit having a series of vertical vents supplying the pressure uniformly, can be built in the foundation beneath the gate.

3d. By the rack-and-pinion plan proposed by Mr. Du Bois. This I believe is a correct principle, but Mr. Du Bois applied it wrongly, and in so unmechanical a manner that it is not surprising that it failed. The device, as Mr. Du Bois applied it, was as follows: Near the upper end of the lower leaf a series of spuds were hinged, having on their lower side a rack which geared into pinions on a shaft located on the foundation near the hinge of the upper leaf. Any movement in the leaves would cause the shaft carrying the pinions to rotate, moving all the spuds simultaneously and being attached to the lower leaf it would consequently be forced to move uniformly. A better plan for using the rack and pinion would be as follows: On the under side of the upper leaf construct racks of the length of the overlap of the leaves. In the upper end of the lower leaf is a shaft of the full length of the dam, which carries pinions, about ten feet apart, meshing into the racks in the upper leaf. These pinions act as rollers to reduce the friction between the leaves. The leaves are united by a sliding link in order to keep the gearing in contact. Experiments made on the rack-and-pinion device with a good-sized model well illustrate the practicability of the plan to prevent warping of the gate, for, however unevenly the pressure is applied, the gate will rise with a uniformly level crest, but on a dam of considerable size a great risk would be taken, as a stoppage in any one pinion would lock the movement of the leaves or cause a breakage. I am firmly of the opinion that the old style bear trap, properly proportioned and built in a substantial manner, reducing the leakage to a minimum, is capable of successful use in spans up to lengths from 200 to 300 feet.

Of the other types of movable dams I believe none would be so

satisfactory as the old style bear trap, on account of its simplicity and few parts, and on rivers like the Ohio, where such large volumes of drift are carried, I believe the Parker, the Lang and the other types referred to would be impracticable.

III. Bear-Trap Gates in the Navigable Pass, Sandy Lake Reservoir Dam, Minnesota.

By Archibald Johnson, U. S. Assistant Engineer, Member of the Civil Engineers' Society of St. Paul.

Sandy Lake Dam is built across Sandy River about one and a quarter miles by river from its confluence with the Mississippi, and about three-fourths of a mile from Sandy Lake.

Its main purpose is to create a reservoir at Sandy Lake, 9.4 feet above extreme low water; but it is intended also to serve a secondary purpose, that of keeping the Mississippi water out of Sandy Lake, should the latter happen to be low when water is liberated from the reservoirs above at any time for the special benefit of navigation.

The river and harbor act of Congress approved July 13, 1892, required the construction of a navigable pass through the dam. As Sandy River, at the dam site, is only about 125 feet wide, it became necessary to use some form of movable dam in place of the ordinary lock gates, so as to retain control of sufficient waterway. By having such, the reservoir, during flood stages in the Mississippi, may sometimes be filled; or, if the flood occurs in the water-shed of Sandy Lake, the surplus may quickly be drawn off. Further, it increases the efficiency of the dam in discharging at any time such volumes as may be desired. As the dam is to be operated with a head on either side, all gates are constructed to act under a direct or a reversed head.

The movable dam adopted for the log-sluice and navigable pass, was the Lang type of the original, or White's, bear-trap gate, with special features for the purposes herein set forth.

The main features of the dam may be briefly described as follows:

It is built of cribwork of 12″ x 12″ pine filled rock and rests on a pile foundation. Commencing at the left bank or south side, we have first the left pier of the log-sluice which is 16′ wide, 116 feet long, and 16 feet high for the first 73 feet from the upper end, then stepping down 2 feet in 9 feet to a height of 10 feet above the floor. At each end is a wing wall 14 feet long extending into the bank. The upper one is 10 feet, and the lower one 8 feet wide. Then comes the log-sluice opening

11 feet wide, controlled by an improved bear-trap gate. Its base or distance from center to center of hinges is 35 feet. Each of its leaves is 21 feet 6 inches, and its idler is 12 feet long. Its construction is such that the idler may be removed from the free end of the downstream leaf and placed on the free end of the upstream leaf after raising the latter until it overlaps the former. It works then for a reversed head, or a head on the downstream side in the same manner as it did for a direct head, or a head on the reservoir side. It has a range of 11 feet above the floor. Next is the right hand log-sluice pier, 12 feet wide, 68 feet long, and 16 feet high, to which is connected the cribwork of five small sluices. This is 34 feet wide, 18 feet long and 16 feet high and is connected on the right with the left hand pier of the navigable pass. Each of these small sluices is 5 feet wide and 4 feet high, controlled by sliding gates in slots, and are operated by worm-gear machines. The left hand pier of the navigable pass is 12 feet wide, 17 feet high, and 249 feet long. Again comes the navigable pass 249 feet long. The pass is controlled by two improved bear-trap gates. Of the length, 249 feet, the fore bay takes up 20 feet, the upper gate 22 feet 3¼ inches, the lock chamber 159 feet 8¾ inches, and the tail bay 20 feet. Lastly is the north shore pier or right hand pier of the navigable pass. It is 17 feet high, 16 feet wide, and 249 feet long, with wing walls similar to those for the south shore pier.

The walls of the log-sluice and navigable pass are lined with 3-inch plank up to the flowage line. The edges of the plank have ½″ x ½″ grooves in which are inserted ½″ x 1″ tongues of seasoned pine. The elevation of the floor of the log-sluice and five small sluices is 1209 feet above sea level, which is about the level of the river channel. The elevation of the floor of the navigable pass is 1208 feet, that of the flowage line 1220 feet, and the top of the cribwork 1225 feet above sea level.

SHEET PILING.

The following are the principal lines of sheeting in the foundation:

There is a line of sheeting extending all around the foundation, and two lines forming diaphragms into the banks from the shore piers. At a distance of 18½ feet from the upper end of the dam, a line of triple-lap-sheeting extends across the foundation, and forms the upper sides of the recesses underneath the log-sluice and upper navigable pass-gates. It is also continuous around the recesses of those gates and around that of the lower navigable pass-gate. These sheet piles were made by fastening together three 2″ x 12″ x 16′ oak plank, allowing the middle one to project out 2 inches, thus forming a tongue on one side and a groove on the other. They were driven with an 1800 pound hammer

and a jet of water from a steam force-pump. Their penetration was from 12 to 14 feet. The material in the foundation is sand, gravel, and some pockets of blue clay.

FILLING BETWEEN AND UNDER CAPS AND BEHIND PIERS.

The space behind piers and between and under caps was filled with material taken out of the foundation, except where concrete was used.

CONCRETE.

The spaces between and under caps in the depressions underneath the log-sluice and navigable pass-gates were filled with concrete. For a distance of 20 feet below the hinges of the lower leaves, and for the same distance above the hinges of the upper leaves, concrete to the depth of 6 inches was put in, excepting a space of about 4 feet next to the hinges of the lower leaves, where gravel was used. The concrete was made of 1 part Louisville cement, 2 parts clean sharp sand, and 4 parts gravel.

CAPS IN FOUNDATION.

The caps under the piers are 12″ x 12″ timbers drift bolted on the heads of the piles. Elsewhere they consist of two 6″ x 12″ timbers screw-bolted to a 6-inch tenon, 12 inches long. At the anchorages the tenons are dovetail in form, being 5 inches thick at the neck and 7 inches at the end. Between the caps in the recesses there are 6″ x 12″ blocks wedged tightly so as to hold the anchorage caps to their work when under an upward strain.

FLOORING.

The flooring of the dam, excepting for 20 feet above and below the gate hinges, consists of two courses of timber. The lower one is 6 inches thick and is fastened to the caps with ½″ x 14″ boat spikes. The second one is 3-inch plank spiked with ⅜″ x 7″ boat spikes. The 3-inch plank in the recesses have ½″ x ½″ grooves in the edges, in which are inserted ½″ x 1″ tongues of seasoned pine. The timbers to which the leaves of the gates are hinged are of white and Norway pine, and are 20 feet long. They form the floor for that distance above and below the hinges. Those in the navigable pass are 11″ x 12″ x 20′, boxed 2 inches on the caps, are screw-bolted together with three lines of 1″ x 24″ bolts, and drift bolted to the caps with 1″ x 20″ drift bolts of round iron. The gains extend 2 inches on each side of the caps for the purpose of keying the timbers to resist a pull or push. After the flooring was laid it was caulked with oakum and cemented under pressure. A 2½″ auger hole was bored about 2 inches in the 3-inch plank, and then through the

rest of the floor with a 2-inch auger. Then a gas pipe 16 feet long was inserted, and through it hydraulic liquid cement was injected.

FLUMES.

In the right hand pier of the log-sluice and in each of the navigable pass piers, are flumes extending from end to end of piers. Each flume is connected with its recess under a gate by a port of suitable dimensions for the purpose of operating the gates by the water pressure due to the head in the pond. Each flume is flared out at the ends in which are grates of ½″ iron to prevent anything larger than an inch in diameter from centering. The floor of the dam is the floor of the flumes, and the construction is such that there can be scarcely any leakage through them when the water in them is under pressure. They are 2 feet high. The available sectional area of the log-sluice flume is 2.83 square feet and that of each of the navigable pass flumes 4.83 square feet.

VALVES.

The flumes at the ports are controlled by circular valves revolving on horizontal axes. On each valve shaft is a large sprocket wheel connected with a small one on a frame at the top of the pier with a combination of chains and rods. On the shaft of the smaller wheel is a 6 foot power wheel for the purpose of operating the valve. The valve is so constructed that when it completely closes the flume on one side of the port, the opposite side is entirely open. Again, as the valve is revolved, for each increment that the flume is opened on one side, the opposite side is closed by a like amount.

NAVIGABLE PASS GATES.

As previously referred to, the navigable pass is controlled by two improved bear-trap gates of the Lang type with some special features. The special feature of these gates is that for a direct head or a head on the lake side, they act as improved bear-trap gates; but for a reversed head they act as old bear-trap gates. The accompanying drawing shows a section through the lower gate when it is up full height as an improved bear-trap gate; also its position when up full height as an old bear trap, and its position when down on its bed. The plan shows the gate lying on its bed.

The valve is shown completely open on the upstream side, thus connecting the recess underneath the gate with the pond. This brings the full pressure due to the head underneath the gate, and its crest will rise to or above the water in the pond, provided the head is greater than that which it takes to start it from its bed. This is true whether it is acting as an improved or as an old bear trap gate. To let the gate down the

valve is turned until the flume is completely closed on the upstream side, and completely opened on the downstream side. The water thus escapes from underneath the gate to the pool below; and, as it is relieved of pressure, it falls until it reaches its bed. For every intermediate position of the valve there is a corresponding head underneath the gate, and the crest of the weir moves accordingly. This enables us to use a gate as a weir discharging any desired depth of water over its crest. The position of the valve for a given flow over the weir is found by trial. The upper gate is similar in all respects to this one, excepting that its base is shorter.

As shown by the drawing, each gate is formed of an upstream and downstream leaf, and a flap or idler. The upper ends of the upstream and lower ends of the downstream leaves are hinged to the floor of the dam with strap hinges on every other timber, excepting the two last ones on the north side, where both timbers have hinges. One end of the idler is hinged to the free end of the downstream leaf and laps and slides on the upstream leaf. To reduce the friction, 5-inch rollers with $\frac{3}{4}''$ journals are placed in the ends of idlers every two feet. Each idler of the navigable pass gates is also provided at the ends with ten valves, $2\frac{1}{2}''$ x $5''$ which revolve on horizontal axes to allow the leakage through the chain holes between the boxes and elsewhere to escape and not act as a weight on the upstream* leaf when the gate is acting as an old bear-trap gate. Their specific gravity is slightly in excess of water, and while the gate is acting as an improved bear trap they are down, and leave no opening at the end of the idler; but under a slight pressure from the opposite direction, it opens. In the timbers in which they are placed slots are cut out for a short distance corresponding to its sectional area. Three-eighths holes were bored in the idler timbers near the hinges to create an air pressure between the idlers and upstream leaves when the gates are acting as old bear-trap gates. The valve is shown in plan in the drawing marked *V*.

The length of the base of the upper gate is 22 feet $3\frac{1}{4}$ inches from center to center of hinges, and that of the lower gate 27 feet. The upper and lower leaves are each $13'\ 9\frac{7}{8}''$ long, the timbers of the upper leaf being $8''$ x $12''$ and that of the lower $9''$ x $12''$ white pine. The timbers of the upstream leaf of the lower gate are $8''$ x $12''$ x $16\frac{1}{2}'$, and that of the downstream leaf $9''$ x $12''$ x $15'\ 7\frac{1}{2}''$ white pine. The idlers of both gates are of oak. The timbers in the idler of the upper gate are $4\frac{1}{4}''$ x $12''$ x $9'$ and those in the idler of the lower gate $4\frac{1}{4}''$ x $12''$ x $11'\ 5\frac{1}{2}''$. Both of these gates have a rise of 12 feet above the floor of the pass.

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* The terms upstream and downstream leaves always refer to such as they are with reference to the direct head.

The timbers of all the leaves including the idlers are screw bolted together with three lines of screw bolts each 2 feet long, one line at the middle and one near each end. There are also in the joints dowels of round iron 2 feet apart. The screw bolts and dowels in the downstream leaves are of 1″ iron; those in the upstream leaves $\frac{7}{8}$″; and those in the idlers $\frac{3}{4}$″ iron. At the free ends of the downstream leaves just below the idler hinges, are two continuous straps of $\frac{1}{2}$″ x 4″ iron on opposite sides bolted together every foot of length by two $\frac{5}{8}$″ bolts. They were put on to bind the timbers of the free ends more firmly together.

To prevent leakage between the timbers of the leaves and idlers, tongues of $\frac{1}{2}$″ x 1″ seasoned pine were inserted in corresponding $\frac{1}{2}$″ x $\frac{1}{2}$″ grooves in the sides.

The side timbers of the leaves have from $\frac{1}{2}$″ to $\frac{3}{4}$″ play at the walls. Oak cleats $1\frac{1}{2}$″ x 5″ with the side next to the wall beveled, were screw bolted to the side timbers with $\frac{5}{8}$″ bolts. After they were bolted on, a saw was run through between the cleats and the walls, leaving a clearance of $\frac{1}{8}$″ to $\frac{3}{16}$″. The same amount of clearance was left at the sides of the idlers, but cleats were not used on them.

The blank timbers in the leaves at their lower ends are connected with the hinged timbers by means of 4″ x 12″ x 18″ oak blocks. These blocks are screw bolted with four 1-inch screw bolts to the blank timbers and lap 3 inches on the adjacent timbers. This transfers the strain due to the pressure on the blank timbers to the hinged timbers. Similar blocks connect the free ends of the blank timbers in the upstream leaves with the adjacent timbers. In this case, however, the bolts pass through the ends of the oak blocks into the hinged timbers. This is to resist the opposite pull of the chains when the gate is up full height as an improved bear-trap.

The free ends of the leaves are connected by $\frac{3}{4}$″ chains 2 feet apart, adjusted as to length so that when the gates fold to their beds there is no appreciable slack. In each of these gates is another set of chains of $\frac{5}{8}$″ iron 2 feet apart, connecting the heel of the down stream leaf with the free end of the upstream, to prevent the latter from leaving the former when the gate is acting as an old bear trap The free end of the upstream leaf is provided with $5\frac{1}{2}$″ rollers with $1\frac{1}{8}$″ journals to reduce the friction between the two leaves while the gate is acting as an old bear trap.

The ends of the timbers in the floor to which the hinges are attached, are anchored to the caps of a row of piles next to the triple lap sheeting by $1\frac{3}{4}$″ bolts 2 feet apart. There are also 1″ screw bolts going through the first cap below the triple lap sheeting. Besides this there are six-inch timbers bolted with drift and screw bolts to the triple lap sheeting. After they were bolted, wedges of hardwood were driven under them, so that when a lift comes on the caps the sheet piling comes into play to resist the upward force.

After the gates were completed a line of three-inch plank was placed at the ends of the timbers to which the lower hinges are attached, the space inside was filled with gravel, and then a liquid hydraulic cement was forced through a 16-foot gas pipe. This was done to cut off the lift on the ends of the timbers when the lower leaves are under pressure. To guard against the effects of a slight lift of the timbers to which the hinges are attached, a slot 2″ x 6″ is cut in each timber just over the triple lap sheeting so as to allow any water to escape in case such should occur. About half way between the first two caps below the hinges a two-inch auger hole was bored in each timber to further facilitate the escape of water that might come from the recess. The chains connecting the heel of the downstream leaves with the free ends of the upstream ones, are provided with turnbuckles at their lower ends; and in adjusting these chains the gates were raised full height as an old bear-trap gate by means of jackscrews, when a uniform tension was put on the chains. By means of tackle the downstream leaves were next raised up full height, when the short chains were subjected to a uniform tension. This was done by means of the staples in the free end of the downstream leaves.

To cause the short chains to draw out of the slots between the boxes of the rollers when the gate is acting under a reversed head 32 pound weights of cast iron were attached to them. It was found by experiment that it required 28 pound weights. After the chains were adjusted the gates were lowered to their beds, and the water in the coffer-dam was allowed to raise over them. It was found that the upstream leaves would not float and that the lower ones would not sink. To change the specific gravity of the upstream leaves, spruce planks were attached near the free ends until they floated. After the idlers were put on, railroad iron was laid transversely across the downstream leaves until the gate would sink in still water. The next test made was to determine the head required to raise each gate from its bed when acting as an improved bear trap. It was found that a static head of 2 inches would raise the upper gate and 3 inches the lower one. No test was made as to the head that would raise the gates while acting as an old bear-trap, as this was impracticable. There has been no opportunity thus far to test the working of the gates under all conditions of backwater.

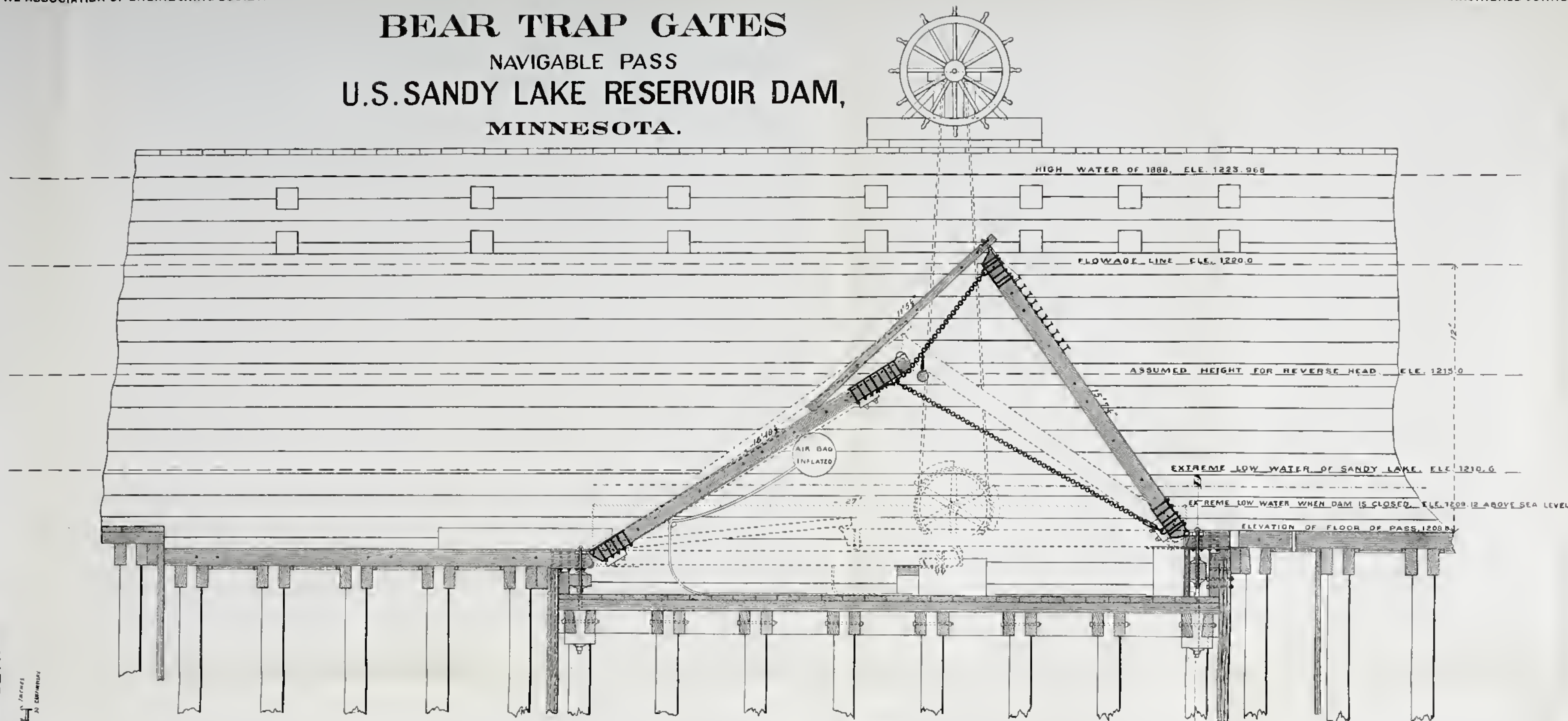
For the conditions of an old bear-trap gate, the leaves of the upper gate bear such proportions to the base, that on the assumption that the gate has a specific gravity of 1, the downward force when water is passing over it when it is down is 0.98 of the upward pressure due to the head; and under similar conditions the downward force is 0.74 of the upward force in the lower gate. It may be noted here that this ratio is a maximum when the gate is down. The lower gate is therefore much more sensitive to a head as an old bear trap than the upper one.

BEAR TRAP GATES

NAVIGABLE PASS

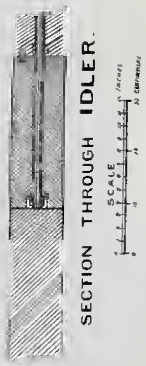
U.S. SANDY LAKE RESERVOIR DAM,

MINNESOTA.

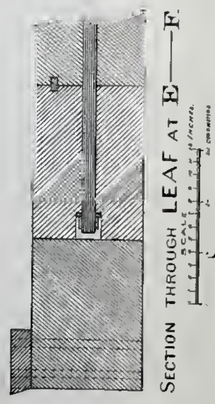


SECTION THROUGH LOWER GATE OF NAVIGABLE PASS AT A——B.

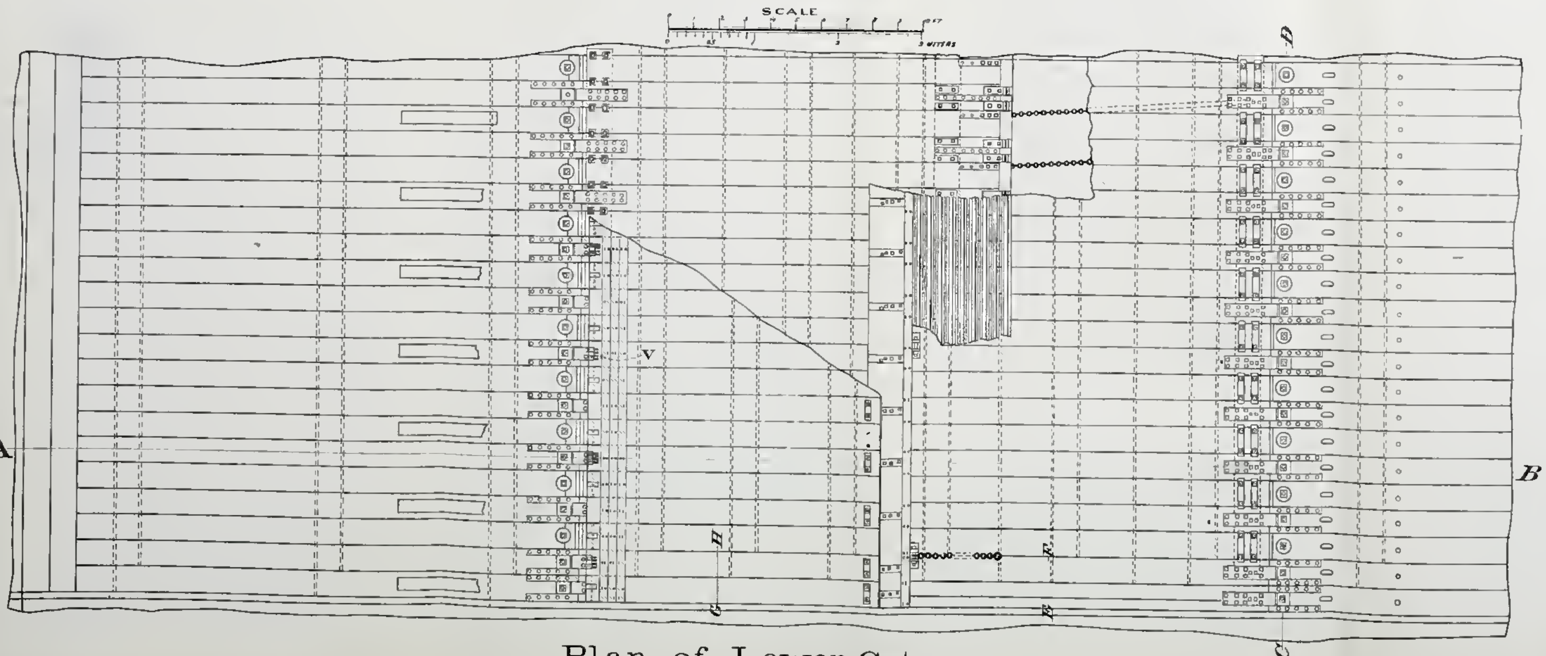
NOTE: A SECTION THROUGH THE UPPER GATE IS SIMILAR, EXCEPTING THAT THE BASE BETWEEN CENTRE OF HINGES IS 22'3¼". EACH OF THE LEAVES 13'9⅞" AND THE IDLER 9' LONG.



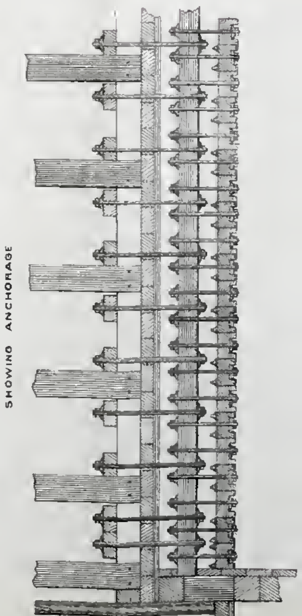
SECTION THROUGH IDLER.



SECTION THROUGH LEAF AT E——F.



Plan of Lower Gate.



SECTION THROUGH C——D

SHOWING ANCHORAGE

AIR BAGS AND CAPSTANS.

When the head is less than two or three inches, or so small that it will not raise the gates, provision was made to raise them above the water so that water may be held on either side of the dam by means of air bags and capstans, either of which is sufficient to raise them. In the navigable pass gates there are attached to each of the upstream leaves four air bags, each 8′ 10″ long and 2 feet in diameter. Each air bag is connected with an air pump on top of the pier with a half inch hose through which air is forced into the bags for inflation. The pipes and valves at the air pump are so arranged that all the air bags may be simultaneously inflated, or one or more may be inflated independently of the others. These air bags are made of 2-ply special woven 16 ounce duck, heavily coated with pure Para gum. In case the air bags should fail, each gate is provided with two powerful capstans which can be connected with ¾″ chains 12 feet long attached to the free ends of the downstream leaves near the sides. Two similar chains are attached 10 feet from the sides, which can be used with derricks should occasion require it.

In the left hand pier there is a 2′ x 3′ flume extending across the pier and intersecting the main flume at right angles. This flume is controlled on each side of the main one by two sliding gates. The object of it is to assist if desired in filling or emptying the chamber. In the right hand pier there is a 2′ x 3′ flume connecting the chamber with the main flume, and is controlled by a sliding gate. The purpose of this one is to assist in emptying the chamber if desired.

Both gates of the navigable pass were made slightly heavier than water, so that when there is no head both gates will fall by their own weight and allow the passage of boats.

In locking a boat upstream it is first brought into the lock. Then the valve of the lower gate is opened upstream, the inside gate in the left hand pier is opened, that in the right hand pier closed, and at the same time the upper gate is lowered so as to allow the water to spill over the crest in any desired amount until the chamber is full. When the chamber is nearly full the upper gate falls. It may be caused to fall sooner if desired by opening the valve completely on the lower side, thus reducing quickly the pressure underneath, until it falls to its bed. When it is down the pressure on it is that due to the head. To lock a boat down, the valve of the upper gate is closed on the downstream side and the crest of the gate raised to the surface of the water by means of the air bags or capstans. Both gates in the 2′ x 3′ flume intersecting the main flume in the left hand piers, and that controlling the 2′ x 3′ flume connecting the chamber with the right hand pier, are opened. At the same time the lower gate is lowered so as to allow a spill over the weir until the chamber is empty and the gate falls to its bed. The lock may be operated

without the use of the small flumes connecting the chamber with the main flumes by filling and emptying the chamber by a discharge over the gates. Further, when the chamber is full, the upper gate may be raised without the use of either the air bags or capstans, by closing its valve on the downstream side and dropping the lower gate until there is a head of about 2 inches on the upper one, when its crest will rise to the surface. Care, however, must be taken that too great a current is not created in the chamber if a boat is in.

The design was made under the direction of Major W. A. Jones for a board of engineers consisting of Major Amos Stickney, Major Alexander Mackenzie, and Captain W. L. Marshall, who recommended its approval to Brig. General Thomas L. Casey, who approved it June 30, 1893.

During its construction I was in local charge. It was completed in October, 1895.

In conclusion I would say that the improved bear trap herein described is the first of this type that was built where the conditions of backwater are variable. In all other cases it was built on a weir or what was equivalent to a weir.

IV. Marshall's Bear-Trap Dams.

By W. L. Marshall, Major, Corps of Engineers, U. S. A., Member Am. S. C. E.

I am glad that the subject of bear-trap dams has been brought up for discussion in a Society of Engineers by so carefully prepared a paper as this of Mr. Powell. For years I have been of the opinion that the best solution of the problem of movable dams will be found in the principle of the so-called American bear-trap dams.

In August, 1889, while I was studying the subject of movable dams for application of some type to Rock River, Illinois, Mr. Parker brought into my office, in Chicago, a model of his recently patented improvement and exhibited it to Brig. Gen. Thos. L. Casey, then Chief of Engineers, U. S. Army, who happened to be on a tour of inspection of my works, and myself.

The General was much interested, and suggested to Mr. Parker the advisability of making the sections of the upstream leaf of unequal width, with a narrower upper section and idler, and myself and some of my assistants, independently, suggested to him the evident possibility of making "the idler" a working part of the device. In subsequent

patents Mr. Parker adopted the unequal sections of upper leaf. The other suggestion was adopted, independently discovered, by Lang, and covered by patent to him.

The Parker and Lang improvements are most valuable, and they directed towards the hinged leaf system my efforts to solve the bear-trap problem.

After discarding the idea of utilizing the idler as a working part of the dam, I adopted the Parker principle in preparing plans for the Illinois and Mississippi Canal, for a movable dam with 100 foot passes, and sluiceways in dams on Rock River. Detailed drawings (now known to be defective in design) of Parker gates were submitted by me to the Chief of Engineers, U. S. A., in June, 1890. Afterwards, in September, 1895, about the time when Mr. Powell prepared his paper, now under discussion, modified forms of bear traps suggested themselves to me. These involved the hinged leaf principle, with the flexible qualities of quadrangular prisms for hydraulic chambers instead of the more rigid triangular forms in use, which, upon analysis, although differing much in form, are so nearly related that they may be described in the same category. I have been requested by Mr. Powell, and by the Secretary of the Civil Engineers' Society of St. Paul, to give drawings, descriptions and mathematical analyses of these gates as part of the discussion, and in the time allowed, with the assistance of Lieut. Henry Jervey, Corps of Engineers, U. S. Army, who has performed the mathematical work relating to both forms of the "Marshall" dam, I am enabled to submit such descriptions, analyses, and outline drawings as will enable any engineer to construct them.

All hitherto known forms of modified bear-trap dams, viz., the "Carro, Girard, Parker, and Lang," have their leaves attached together at the crest of the dam, and their hydraulic chambers triangular prisms, when the dams are at full height. In the "Girard, Parker and Lang" types, with hinged leaves, in intermediate positions the hydraulic chambers are quadrangular prisms, with one re-entrant angle projected into the hydraulic chamber.

In the "Marshall" gates (Plate B) one leaf projects beyond the line of attachment of the two leaves, at least one-half the width of the projecting leaf. The hydraulic chambers are in all cases quadrangular prisms with salient angles, or the joint in the downstream leaf is always projected out from the hydraulic chambers and downstream from the lower foundation hinge. The joint always forms a knuckle downstream. There are no restraining chains or stops, but the ultimate positions of the gates are determined by equilibrium of water pressure and weight of gates only.

When the downstream leaf is extended above the upstream leaf

(Plate B, Fig. 1) the combined width of the two sections of the downstream leaf should be equal to, or less than the width of the upstream leaf; the line of attachment of the two leaves should be at, or slightly below the middle line of the downstream leaf (counting both sections), or at, or slightly below the lowest possible center of pressure of the water on the upper section of the downstream leaf, but above all possible centers of pressure on the downstream leaf, including both sections.

The lower section of the downstream leaf is always to be, as near as practicable, equal in width to the distance from the downstream knuckle to the line of attachment of the two leaves.

The hydraulic chamber, therefore, in this form (No. 1) is always a quadrangular prism with salient angles, inasmuch as the angle at the knuckle can never become as great as 180 degrees, with a reasonable fall over the dam. The sides of this prism are equal two and two in width, but the sets of two unequal. The equal sets of two sides in this form are connected together, with the vertex of the wider set upstream, at foundation.

In this form, not only does the gate rise by the pressure of the initial head on the components of the downstream leaf forming part of the hydraulic chamber, but also from the direct pressure of the water in the upper pool on the projecting surface of the downstream leaf, and the gate will rise as fast as the hydraulic chamber may be filled. Whatever be the height of water above the crest of the dam, or the extent of backwater, as long as the exit of the hydraulic chamber is closed and the inlet open, the center of pressure upon the downstream leaf will fall below the hinged axis of attachment of leaves, and, consequently, the downstream knuckle angle will project from the hydraulic chamber. As the backwater rises the gate will rise, and in case the dam is allowed to be totally backed out with but a slight current over it, the gate will reach its maximum height and occupy such a position of unstable equilibrium that a rapid opening of the outlet valve to full extent, and closing the inlet, might possibly result in a reversal and failure of this gate; *i. e*, as the backwater rises the gate becomes more and more difficult to lower, or the moments of the lifting and depressing forces become more nearly equal, and at the extreme, when entirely submerged, if it be not made heavier than water, the gate cannot be lowered at all. If made heavier than water it will then fall flat. Ordinarily the backwater will not be allowed much above the half height of the dam, and under these conditions, or with any working or appreciable head, it is easily worked and lowered, but on account of its form, which involves an apron above the dam to prevent drift accumulations, and a motion of its crest upstream in lowering, but little value is assigned to this form of the "Marshall" bear trap, in comparison with the design

No. 2. It is believed, however, to be comparable in utility to forms that are in use, and in special cases superior in some respects to them.

In the second form of this invention (Plate B, Figs. 2 and 4) the *upstream leaf* is extended one-half its width beyond the axis of junction between the leaves. The downstream leaf is in two unequal sections, hinged together, with downstream projecting knuckle, and is hinged to the upstream leaf and foundation so as to form a hydraulic chamber in the form of a parallelopipedon, with its longer sides respectively coincident with and parallel to the base of the dam or plane of foundation hinges; the shorter sides being in width equal (as nearly as practicable for material forms) to one-half the width of the projecting leaf.

This form differs from all previous forms in this—that the resultant of all forces acting on the dam to move it bodily, is directed downwards through the base of the dam, to insure stability, and not upwards to overturn it, or to require heavy foundation anchorages *; also that all

* In all forms of bear-trap dams having the downstream leaf constituting the dam, the pressure on the dam is directed obliqnely upward, to tear the effective leaf away from the foundation. In these dams, properly speaking, there is no hydraulic chamber. In raising the dam the upstream leaf is simply a screen to allow the water in the upper pool to be gradually applied to the downstream leaf, and a governor or restraint upon the motion of this leaf. When the dam is raised to full height the upper leaf is simply a tie to hold the gate against overturning, and must be anchored to the foundation.

This anchor may be the weight of water on the foundation, or a mass of masonry underneath the foundation, or the abutment walls on top the foundation. In lowering such dams the greater pressure is transferred to the upstream leaf, and the dam is removed, but still there must be anchorage to foundation, till the dam is thrown down.

In Marshall's dam No. 2, the upstream leaf forms the dam. The pressure thereon is always, whether in rising or falling, obliquely downward. The hydraulic chamber is below the dam, in the lower pool, and is a veritable closed hydraulic press, the distention of which raises the dam and the collapse of which allows it to lower. The weight or mass of water on the foundation above or below the dam is not a factor in the case. Steam, air, gas or anything producing distention of the closed chamber will raise the dam, and the water pressure of the upper pool is not at all restrained in its direct action on the dam.

It is only necessary that the hydraulic chamber have tight, strong sides and joints, and the dam as a whole be prevented from sliding down stream on the foundation. There is no tendency to pull the dam away from the foundation.

To get a clearer perception of these facts, imagine the upper and lower pools to be separated by an absolutely water-tight diaphragm extending below the bottom edges of the effective leaves or dams when raised.

In this case in triangular dams the so-called hydraulic chambers form parts of the upper pool; in Marshall's No. 2 of the lower pool. By leakage through floors or otherwise the hydraulic pressures under the hydraulic chambers will be equalized with that in the pools in which respectively the hydraulic chambers are located.

movements of all parts of the dam are downstream in lowering it, and, consequently, the lowering of the dam can never possibly be interfered with by accumulations of ice or other drift.

Both forms of "Marshall's" bear-trap dam depend upon the principle that if any obliqued angled quadrangular prism having its sides equal in sets of two, the sets unequal, be subjected to external pressure on its sides directed inwards, it will collapse or fall flat, the longer sides approaching each other. If subjected to an internal pressure directed outward, the sides will move apart (or rise) until the interior volume of the prism becomes a maximum, which will occur when the shorter sides are perpendicular to the longer sides.

If subjected at the same time to an internal pressure directed outwards, equal upon each superficial unit of interior surface on opposing sides, and to an external pressure on one side directed inward, the prism will take some position between its maximum and minimum volumes.

The triangular dams under such conditions will turn over down stream if not securely anchored to the foundation above, and be destroyed as dams.

The Marshall No. 2 will require only restraint against sliding down stream.

In triangular dams there must be anchors to hold down the dam, which is the downstream leaf, and sheet piling under it, to prevent undercutting in the direction of flow.

By careful sheet piling above the base of the so-called hydraulic chamber in triangular dams, and perfect sub-drainage of foundation into the lower pool to prevent equalization of pressures above and beneath the hydraulic chamber (so-called), the weight of water may suffice on stiff floors for anchorage. This practically makes the foundation of the dam and the sheet piling under the dam a necessary part of the dam or of the downstream leaf, but the foundation is parallel to the restrained current, and cannot in any sense constitute a "dam" or part thereof. If now from any cause this sub-drainage becomes clogged or ineffective then the dam may be destroyed, or depend for stability upon the weight of artificial masses or upon the weight and transverse strength of the floor system upstream from the effective leaf of the dam. It is assumed in the text that the leaf which (with subsheeting directly in continuation of it) obstructs by most direct means the horizontal motion of the water, constitutes the dam.

In Marshall's No. 2, the dam is the upstream leaf, with sheet-piling to prevent undercutting. The hydraulic chamber is simply a motive power, and its action is as positive as that of any lifting jack or press, that may be independent of the weight or body lifted. The stability of the dam is in no wise dependent upon the internal pressures within the lifting jack or hydraulic chamber; nor upon its weight nor upon differential pressures on its sides, and this constitutes the material difference between Marshall's No. 2, and all other forms of Bear-Trap dams, as claimed in the text. In this connection attention is invited to Plate B, Fig. 4, where it is distinctly shown that the hydraulic chamber is simply a strut or prop under the dam when at rest, and a lifting jack when in motion, that may not be attached to the dam at all, further than at lowest points to prevent separation of joints by floatation, or to insure constant contact between joints of the hydraulic chamber.

In Form No. 1 of this dam, if the material be of no weight, the maximum height of dam corresponding to the maximum practicable volume of the hydraulic chamber will occur when the dam becomes submerged, or the backwater at or above the crest of the dam, and but little or no fall over it. The minimum height raised will occur when there is no backwater at all and the water in upper pool just at the crest of the dam.

In the latter case the height of the dam above the plane of foundation hinges will be 75 per cent. of the distance between these axes. In the former it will be about 91 per cent. of this base.

In Form No. 2 the ordinary height of dam will correspond with no backwater. As the backwater rises the gate will also rise until the backwater reaches the surface of the upper section of the lower leaf. It then, as the backwater rises, slowly lowers till submerged.

This form will not rise at all unless the upper section of the downstream leaf exceeds in width two-thirds the width of the upstream leaf. The relations between the angle of rise, and the width of leaves when there is no backwater is expressed by the equation $Z = \frac{2X}{3 \cos \propto}$ in which

Z = width of upper section of downstream leaf,

X = width of upstream leaf,

$\propto$ = angle of rise between upstream leaf and plane of foundation hinges.

Where $\propto$ equals 45 degrees then Z equals .943 X, and the height of the gate will be 75 per cent. of the distance between the hinges, as in the first form with no backwater. It is considered better to make the upper sections of the downstream leaf in width equal to or greater than the width of the upstream leaf in order to increase the angle of rise, or rather the lifting force. The advantageous angles of rise vary between 45 degrees and 65 degrees. Angles less than 60 degrees are not advantageous when constant backwater rises much above the upper section of downstream leaf. The height of dam may be regulated by the supply and exit valves between its maximum and minimum angles, and it is well to provide for a greater force than necessary to maintain the dam at the required height, to guard against unforeseen or indeterminate depressing forces. It would be well to proportion the upper section of downstream leaf for an angle say, 5 degrees greater than it is intended to keep the dam, to provide sufficient margin.

There are several remarkable features to be observed in this form of dam. The mathematical relations of its parts depend upon the properties of parallelograms, and are, therefore, such as to make all calculations of stresses and dimensions extremely simple; the angles are such that packing all joints where leakage can occur except at the one acute angle at the downstream knuckle, is easily and cheaply effected. The

flexibility of both forms is greater than can be found in any other form of bear-trap dam. No sudden strain can possibly be brought upon any part of either form of the dam, and anything like the action of a hydraulic ram is impossible. In all other forms ramming action is possible, and chains or other stops are necessary, which, without care, may be carried away or broken.

Attention has already been called to the fact that the resultant of all forces acting on the effective leaf of Form 2 is toward and through the foundation; not upward, or from it. There is also another peculiarity of Form 2, *i. e.*, the horizontal force acting to push the system downstream, or to lower the dam, as long as there be no backwater, and as long as the upper pool reaches just to the top of the upstream leaf, is constant and equal to the pressure on that leaf when it stands vertical with water at its crest, and no backwater. This form is believed to be the most sensitive and responsive of all bear traps; the effective lifting moment in proportion to the depressing moment of available head is a maximum at the lowest position of the gate; a minimum at the highest when the moments become equal. The horizontal depressing force as shown, is constant, at all angles of rise, except that when there be backwater, or still water, rather, it is necessary to depend upon its weight to close it down flat, as in the case of all bear traps. The objection to this form is the vertical fall from the crest of the dam to the upper surface of the lower leaf, and the possibility of drift accumulations in the acute angles below the crest. Where this objection is good the usual resort to inclined downstream aprons (which need not be heavy) may be taken. In many cases of clear water streams, and in raised sluices, the aprons may not be found necessary.

The great difficulty in all bear-trap dams is to move the gates when entirely submerged. When there is a sufficient current or fall over them to create an effective hydraulic head due velocity these gates may be raised and lowered even when made of equal, or somewhat greater or less specific gravity than water. It is not likely even if made of metal, that the weight to be moved will be greater than equivalent to a six-inch head of water which is produced by a current somewhat less than six feet per second. In slack water and moderate currents it is better to make the gates heavy enough to readily sink to rest, and to supply a working head either by taking the water through conduits leading a sufficient distance above the outlet, or else to provide an auxiliary head by reservoir on the bank or otherwise.

Some bear-trap dams, particularly of types like the "Lang, Carro, and Du Bois," on account of the necessity for rollers to diminish sliding friction in lowering, offer joints through which there may be much leakage from the upper pool into the hydraulic chamber, and have been

made with such restricted outlet ports that the dams cannot be lowered below a certain level.

In any type the ports should be made capacious, so that a very small head will cause a greater flow out of the hydraulic chamber than can possibly leak into it from the upper pool, under any head that may be encountered in lowering the dam, and to discharge a sufficient volume under minute heads, such as the weight of the gate in slack water.

In Form No. 2 of the "Marshall" dam the joint at the foot of the upstream leaf is of such angle always that it may be made nearly absolutely water tight by a covering strip of sheet rubber packing. The joint next the abutment is less than one-half the development of any other type of bear-trap dam. Comparative drawings are given herewith that show the materially less volume of hydraulic chamber in the "Marshall" dam than in the triangular forms. Ports, therefore, of any definite size will supply a "Marshall" dam when they will not suffice for any dam of the usual form of the same height and length of crest. Both forms give higher dams in proportion to distance between foundation supports than any other type, which may be as easily worked.

Instead of hinging the leaves of Form No. 2 rigidly together, which requires very careful adjustment of four parallel axes of rotation, and will also bring tensile stress on the upstream leaf and also on the lower section of downstream leaf, the gate may be made without any hinges permanently attached to the leaves at junctions, but with quoins only, and limiting straps.

Fig. 4, Plate B, represents this arrangement by which the upper section downstream leaf is kept parallel with the plane of the lower axes of the gate by parallel eyebars. These eyebars take all the tensile stresses in the system, and the actions of the forces on the leaves themselves result in pressing them together along quoins or sockets of junction, thus making possible absolutely water-tight joints throughout the system without packing of any kind.

The construction permits long horizontal leaves of light construction by reason of the intermediate supports which may be increased in number.

In this method of construction it is only necessary to provide such straps, collars, or ligatures as may prevent the parts separating so far as to fall out of the sockets or quoins. Quite free play may be safely allowed, and the difficulty incident to all hinged leaf bear-trap dams of constructing four parallel continuous axes, may be largely avoided.

It is necessary to have the foundation quoins parallel and the leaves exact rectangles. The eyebars need be of exactly the same length, etc., but it is not necessary that all the forward or all the rear eyebars

lie in a plane. The points of attachment of each bar to leaf and foundation must properly correspond, so that equal sectors of circles shall be described by the bars and the resultant upward pressure on the horizontal leaf pass midway between the eyebars, in any given section of the dam.

It is evident that if the leaves be heavier than water (so that the upstream leaf may not float out of its quoin at bottom), no rigid connections between the leaves will be required—the eyebars being the only neccessary attachments in that case to horizontal leaf and bottom of hydraulic chamber. Collars or straps at ends of gate leaves, similar to what are used at tops of mitred lock gates, are advisable as making the gate more secure against accidental causes of displacement. These collars may allow some play so long as the leaf is prevented leaving the socket. This property of Form 2, by which compressive forces may be utilized to make tight joints in hydraulic chamber, is enjoyed only by this form of bear-trap dam.

Form No. 2, in which the upper section of the downstream leaf moves parallel always to its original position, has suggested to the writer the possibility of building very long dams in sections, the alternate sections being "abutment sections" formed by suspending from the upper section of downstream leaf at the ends thereof, a diaphragm of sufficient strength that rises and falls with the section into a narrow slot prepared below the foundation.

These abutment sections may be raised independently, and the intermediate sections afterwards, or the whole dam of any length whatever be put up at once, all sections rising nearly simultaneously. The full details of this arrangement are too voluminous for this paper, and have not been sufficiently perfected for publication as yet.

The drawings and mathematical discussion by Lieut. Jervey, Corps of Engineers, U. S. A., appended hereto, will fully explain these new types of bear-trap dams.

In designing them, more careful attention must be given to these analyses, in Form No. 2 especially, and to carefully proportioning the relative dimensions, than in other forms of bear-trap dams, because their limits of rise, etc., are fixed or determined by the natural forces acting on the dams, and not in any way restricted by the introduction of outside resistances or stops.

MARSHALL'S BEAR-TRAP DAM, NO. 1.

MATHEMATICAL ANALYSIS.

By Henry Jervey, First Lieutenant, Corps of Engineers, U. S. A.

Refer to figures on Plate A, 1 to 8 inclusive.

Denote lengths of upstream leaf and of lower and upper sections of downstream leaf by X, Y and Z, respectively.

Let X be attached to Z, so that Fig. 1, $FE = EG = Y$, and let $DG = X$.

Let θ, θ' and φ represent the angles shown in Fig. 1.

Under the conditions mentioned we may readily deduce the following equations:

$$\sin \varphi = \frac{2 X \sin \theta (X \cos \theta + Y)}{X^2 + Y^2 + 2 XY \cos \theta} \tag{1}$$

$$\cos \varphi = 1 - \frac{2 X^2 \sin^2 \theta}{X^2 + Y^2 + 2 XY \cos \theta} \tag{2}$$

$$\sin \theta' = \frac{(X^2 - Y^2) \sin \theta}{2 XY \cos \theta + X^2 + Y^2} \tag{3}$$

from which corresponding values of φ and θ' may be deduced for all values of θ, which is assumed to be the independent variable.

If (Fig. 1) we make the further assumptions that $X = 4\ Y$ equations (1), (2) and (3) reduce to

$$\sin \varphi = \frac{8 \sin \theta (4 \cos \theta + 1)}{17 + 8 \cos \theta} \tag{4}$$

$$\cos \varphi = 1 - \frac{32 \sin^2 \theta}{17 + 8 \cos \theta} = \frac{8 \cos \theta (4 \cos \theta + 1) - 15}{17 + 8 \cos \theta} \tag{5}$$

$$\sin \theta' = \frac{15 \sin \theta}{17 + 8 \cos \theta} \tag{6}$$

To determine the position of equilibrium of the rising and falling bear-trap dam under consideration, let us make the following additional assumptions to apply in every case:

1. That the surface of water in the upper pool remains constantly coincident with the crest of the dam.
2. That the leaves of the dam may be reduced to surfaces, having neither weight nor volume.
3. That friction may be neglected.
4. That w = weight of 1 cubic foot of water.
5. That $Z = 3\ Y$.

CASE I.—DAM RISING.

Hydraulic chamber in communication with upper pool only.

Under such conditions the water pressure will be the same on both sides of X (Fig. 1), and may be neglected in this discussion; the pressures on Z and Y are the only forces tending to produce motion in the dam.

(a) When there is no backwater, Fig. 2:

P_1 acts at F, (EF being $\frac{1}{3}$ EB) and

$$P_1 = \frac{3\ Yh''\ .\ w}{2} \tag{7}$$

Pressure on Y has components P_2 and P_3, former has no tendency to cause motion:

$$P_3 = \left(\frac{Yh''}{2} + \frac{Yh'''}{6}\right) w \tag{8}$$

For equilibrium we must have, denoting the lever arm of P_1 cot θ by l, which is equal to Y sin φ,

$$P_3\ .\ Y = l.\ P_1\ .\ \cot\theta = P_1\ .\ Y\ .\ \cot\theta \sin\varphi$$

whence, since $h'' = 3\ Y \sin\theta'$ and $h''' = Y \sin\theta$,

and by omitting factors Y and w, we obtain

$$\frac{3 \sin\theta'}{2} + \frac{\sin\theta}{6} = \frac{9 \sin\theta'\ .\ \cot\theta \sin\varphi}{2} \tag{9}$$

Substituting from equations (4), (5) and (6), and reducing, we obtain

$$\cos^2\theta + .1464 \cos\theta = .2003 \tag{10}$$

Whence $\cos\theta = .3803$ and $\theta = 67°\ 39'$

$\therefore \sin\theta' = .6921$ and

$$h'' + h''' = .7503\ X \text{ or} \tag{11}$$

Height of crest = .7503 length of base.

(b) When level of lower pool is at E, Fig. 3.

$$P_1 \text{ (as in "a,"} = \frac{3\ Yh''.\ w\ .}{2} = \frac{9\ Y^2 \sin\theta'\ .\ w\ .}{2} \tag{7}$$

but

$$P_3 = \frac{Yh''\ .\ w\ .}{2} = \frac{3\ Y^2 \sin\theta'\ w}{2} \tag{12}$$

Substituting in equation (8) of equilibrium, we obtain finally

$$1 = 3 \cot\theta \sin\varphi \tag{13}$$

whence

$$\cos^2\theta + \frac{\cos\theta}{6} = \tfrac{17}{96}$$

$\therefore \cos \theta = .3693;\ \theta = 68° \ 20'$
$\therefore \sin \theta' = .6986$ and
$h'' + h''' = .7556\ X.$

(*c*) When level of lower pool is at *F*, Fig. 4.

$$P_1 = 2\ Y(h'' - Y \sin \theta')\ w\ .$$
$$P_a = \tfrac{13}{12}\ P_1$$
$$P_1 = P_a - P_b$$
$$P_6 = \frac{P_1}{12}$$
$$P_b = P_a \cot \theta = \tfrac{13}{6}\ Y\ .\ w\ (h'' - Y \sin \theta') \cot \theta \tag{14}$$
$$P_5 = -P_b \cot \varphi = \frac{Y\ .\ w\ .\ (h'' - Y \sin \theta') \cot \varphi}{6} \tag{15}$$
$$P_3 = \frac{w\ .\ Y(h'' - Y \sin \theta')}{2} \tag{16}$$

For equilibrium [compare equation (8)]

$$(P_6 + P_5)\ .\ Y \sin \varphi = P_3\ .\ Y \tag{17}$$

Substituting values from (14), (15) and (16) and cancelling common factor $Y^2\ .\ w\ (h'' - Y \sin \theta')$, we obtain:

$$\sin \varphi\ (13 \cot \theta - \cot \varphi) = 3 \tag{18}$$

and by substitution from (4) (5) & (6) and reduction we obtain

$32 \cos^2 \theta + 6 \cos \theta = 3$
$\therefore \cos \theta = .22647;\ \theta = 76° \ 54' \ 38''.4$
$\sin \theta = .9740$
$\sin \theta' = .7766$
$h'' + h''' \quad .826\ X.$

If $\theta = 90°$, which will occur just as the backwater level reaches the crest of the dam, the dam will attain its maximum height of crest $= .912\ X.$ This position is shown in Fig. 5, which also shows the path of the upper edge of leaf *Z* as the dam rises or falls.

Referring to the figures on Plate A, it is observed that the forces tending to produce motion become less as the backwater rises in level and reach zero just as the dam is drowned out, leaving the dam in a state of unstable equilibrium and liable to be overturned by a current over its crest if outlets of hydraulic chamber are suddenly opened and inlets closed.

CASE II.—DAM FALLING.

Hydraulic chamber in communication with lower pool through outlet ports.

In actually lowering the dam the inlet ports of the hydraulic chamber would be slowly closed *pari passu* with the opening of the outlets; this is equivalent to a small (differential) discharge from the hydraulic chamber into the lower pool. Inasmuch as any removal of water from the hydraulic chamber, considered air-tight, creates a vacuum therein, this discharge brings an atmospheric pressure on the exterior of the hydraulic chamber, tending to reduce its volume and, therefore, to lower the dam, thus assisting the head of water acting directly on the leaf X; and the total pressure on this leaf is, therefore, due to the difference of level of the upper and lower pools.

a.—WHEN THERE IS NO BACKWATER.

Referring to Fig. 1, Plate A:

Suppose the leaf X perfectly free to move it will follow the receding water in the hydraulic chamber and thus the latter will remain always full. The leaf X will sustain the full head $h'' + h'''$ acting through its center with lever arm $\frac{X}{2}$ to turn X downward about D.

This pressure denoted by

$$P_X = X \,.\, w\,(h'' + h''') = 4\ Y^2 \,.\, w\,(3 \sin \theta' + \sin \theta)$$

and its moment about D is

$$M_X = P_X\, 2\ Y \,. = 8\ Y^3 \,.\, w\,(3 \sin \theta' + \sin \theta)$$

The pressure on Z acts at $\frac{FB}{3}$ from F and is due to head

$$\frac{h''}{3} = Y \sin \theta'.$$

Therefore

$$P_1 = 2\ Y^2 \,.\, w \,.\, \sin \theta'$$

and its parallel components at F and E are respectively

$$\frac{5}{3} P_1 = \frac{10}{3}\ Y^2 \,.\, w \,.\, \sin \theta'$$

and

$$-\frac{2}{3} P_1 = -\frac{4}{3}\ Y^2 \,.\, w \,.\, \sin \theta'$$

The sum of the components of these in direction of Z gives the resultant.

$$R_Z = \frac{Y^2 \,.\, w \,.\, \sin.\ \theta'\ (10\ \cot.\ \theta - 4\ \cot.\ \varphi)}{3}$$

and its moment to raise the dam about D is

$$M_Z = R_Z \,.\, X \sin.\ \theta = \frac{4\,Y^3\ .w \sin\ \theta\ \sin\ \theta'\ (10 \cot \theta - 4\ \cot.\ \varphi)}{3}$$

which by reduction becomes

$$M_Z = Y.^3\, w \frac{20 \sin.\ \theta}{17 + 8 \cos.\ \theta} \left(6 \cos.\ \theta + \frac{15}{2 + 8 \cos.\ \theta} \right)$$

By similar reduction we obtain

$$M_X = 8\,Y^3.\ w \sin.\ \theta\ \frac{(62 + 8 \cos.\ \theta)}{(17 + 8 \cos.\ \theta)}$$

If $\theta = 60°$; $\cos.\ \theta = \frac{1}{2}$; . $\sin.\ \theta = \frac{\sqrt{3}}{2}$ and

$$M_Z = \frac{110\ Y^3 . w . \sin.\ \theta}{21} = 4.54\ Y^3 . w$$

$$M_X = \frac{176\ Y^3 . w . \sin.\ \theta}{7} = 21.77\ Y^3 . w$$

If $\cos.\ \theta = \frac{3}{4}$; $\sin.\ \theta = \frac{\sqrt{7}}{4}$ and

$$M_Z = 3.65\ Y^3 . w$$

$$M_X = 15.61\ Y^3 . w$$

If $\theta = 67°\ 39''$ [See eq'n (10)]; $\sin.\ \theta = .925$; $\cos.\ \theta = .38$.

$$M_Z = 4.86\ Y^3 . w. \qquad M_X = 24.01\ Y^3 . w$$

M_X will always be greater than M_Z.

The dam will, therefore, be easily lowered from its highest position for "no backwater," provided this condition always exists. In lowering an actual dam, however, the backwater would rise relatively to the crest of the dam and, therefore, it is necessary to show that the dam can be lowered for all relative heights of lower and upper pools.

b.—BACKWATER AT F. (FIGS. 1 AND 6, PL. A.)

$$P_X = 8\ Y^2 . w . \sin\ \theta'$$

$$M_X = 16\ Y^3 . w . \sin\ \theta'$$

or by reduction

$$M_X = Y^3 . w \sin.\ \theta\ \frac{240}{17 + 8 \cos.\ \theta}$$

and as in preceding case of "no backwater"

$$M_Z = Y^3 . w\ \frac{20 \sin\ \theta}{17 + 8 \cos.\ \theta} \left(6 \cos.\ \theta + \frac{15}{2 + 8 \cos.\ \theta}\right)$$

If $\theta = 76°\ 54'$ [See eq'n (18)]; $\cos.\ \theta = .226$; $\sin.\ \theta = .974$; this being the position of equilibrium attained by the rising dam, when backwater level is at F, we obtain

$$M_Z = 5.49\ Y^3 . w$$

$$M_X = 12.43\ Y^3 . w$$

If $\theta = 60°$; $\cos.\ \theta = \frac{1}{2}$; $\sin.\ \theta = \sqrt{\frac{3}{2}}$

$$M_Z = 4.54\ Y^3 . w$$

$$M_X = 9.90\ Y^3 . w$$

Examining the values of M_X and M_Z we find the former to be the greater for all values of θ; that is, the dam can be lowered when the backwater remains at the level of the junction between upper and lower gates.

c.—BACKWATER AT CREST OF GATE.

In this case both M_X and M_Z reduce to zero and the dam cannot be lowered unless it is heavier than water or unless the hydraulic chamber can be emptied to a level independent of the lower pool. In the latter case, if the outlet valves are suddenly opened there will be great probability of the dam overturning by θ becoming greater than 90°, and the volume of the hydraulic chamber thereby reduced.

For levels of backwater between F and the crest the moments M_X and M_Z will become smaller and approach equality as the level of backwater rises, but M_X is always the greater until the crest of the dam is reached.

MARSHALL'S BEAR-TRAP DAM, NO. 2.

MATHEMATICAL ANALYSIS.

By Henry Jervey, First Lieutenant, Corps of Engineers, U. S. A.

I.—GENERAL SOLUTION.

Referring to Fig. 9, Plate A, let DB represent the upstream leaf of the dam, FEG the hinged downstream leaf.

Assume DF and FE to be always equal and parallel to EG and GD respectively, making the right cross-section of the hydraulic chamber a parallelogram.

Denote distances and dimensions as follows, all expressed in feet:

$X =$ width of leaf DB.

$Z =$ width of leaf FE.

$Y =$ width of leaf $GE = FD$.

$h' =$ depth of center of X below surface of upperf pool.

$h'' =$ depth of junction of leaves below surface of upper pool.

$H =$ depth of foundation hinges below surface of upper pool.

$h =$ depth of backwater above foundation hinge when level of lower pool is at or below E.

$h''' =$ depth of E below surface of lower pool.

Let

$\alpha =$ angle FDG expressed in degrees, minutes and seconds.

$w =$ weight of one cubic foot of water in pounds.

$P =$ water pressure due to h' on leaf X in pounds.

$2P_1 =$ water pressure due to h'' on leaf Z in pounds.

$P_2 =$ backwater pressure due to h on leaf Y in pounds.

Consider the dam to be one (1) foot long at crest, and the figure to represent a right cross-section: therefore, assuming surface of upper pool to be always level with the crest of the dam, we have

$P = X \,.\, h' \,.\, w \,.$ pounds $= .5\, X^2 \,.\, w \,.\, \sin \propto$ pounds. (1)

The center of pressure on X is at M, MD being $\frac{1}{3}\, X$, therefore the moment of P about D, tending to lower the dam, is

$P \,.\, \overline{MO} = .167\, X^3 \,.\, w \,.\, \sin \propto$ foot-pounds. (2)

Considering the interior of the hydraulic chamber, the surfaces FD and GE, being equal and under the same head of water, will be subjected to equal interior pressures; the moments of these pressures neutralize each other and there will remain only the upward pressure, $2P_1$, on Z tending to raise the dam $2P_1$ has equal components at E and F normal to X and Y; these may be considered as both acting at F, with lever arm $FD = Y$, to turn X about D.

From our notation we may write, Fig. 9, Plate A.

$2\, P_1 = Z \,.\, h'' \,.\, w \,.$ pounds $= Z \,.\, w. \,(X - Y) \sin \propto$ lbs. (3)

$\therefore 2\, P_1' = 2\, P_1 \cos \propto = Z \,.\, w\, (X - Y) \sin \propto \cos \propto$ pounds.

and

$2\, P_1' \,.\, \overline{FD} = Z \,.\, Y \,.\, w\, (X - Y) \sin \propto \cos \propto$ foot-pounds. (4)

For backwater pressure, level at or below E

$P_2 = .5\, h \,.\, \overline{GK} \,.\, w \,.$ lbs $= .5\, w \,.\, \dfrac{h^2}{\sin \propto}$ pounds (5)

and its moment about EG to raise the dam is

$P_2 \,.\, \dfrac{\overline{KG}}{3} = .167\, w \,.\, \dfrac{h^3}{\sin^2 \propto}$ foot-pounds. (6)

When backwater rises above E, the *additional* head h''' acts at centers of Y and Z and the center of pressure of that part of X between F and the surface of the lower pool. Since X and Y are parallel we may, without affecting resultant moment about D or G, consider Y extended to surface of water and pressed by back head of water $\underline{h + h'''}$ acting at $\frac{1}{3}$ the distance from G to surface of backwater.

Let P_4 = pressure in lbs on Z due to head h'''

Let P_3 = pressure in lbs on $Y + ET$ due to head h.

Let $h''' = m\, (X - Y) \sin \propto$, m being any proper fraction $= \dfrac{FS}{FB}$

From the laws of pressure

$P_3 = .5\, [Y + m\, (X - Y)]^2\, w \,.\, \sin \propto \; = .5\, (h + h''')$
$(GE + ET)\, w \sin \propto$ (7)

and its moment about G is

$P_3 \,.\, \overline{NG} = .167\, [Y + m\, (X - Y)]^3\, w \,.\, \sin \propto$ foot-pounds (8)

tending to raise the dam.

$P_4 = Z \,.\, m\, (X - Y) \sin \propto \,.\, w$ pounds. (9)

It may be considered acting at either E or F (EF being rigid) with its entire component,

$P_4 \cos \propto$ perpendicular to X and Y and tending to lower the dam with its moment given by the equation

$$P_4 \cos \propto . Y = Z . Y. m . w (X - Y) \sin \propto \cos \propto \text{ foot-pounds.} \quad (10)$$

The dam will take a position of equilibrium under any given conditions when the resultant of all the moments tending to raise the dam is equal to the resultant of all those tending to lower it.

Let us neglect in every case friction and effects due to currents, assuming, also, that the leaves of the dam are reduced to surfaces having neither weight nor volume:—

a.—WHEN THERE IS NO BACKWATER.

Equations (2) and (4) give the values of the opposing moments under this condition. Placing them equal to each other we obtain

$.167 X^3 w . \sin \propto = Z . Y . w (X - Y) \sin \propto \cos \propto$ or by reduction

$$.167 X^3 = Z . Y . (X - Y) \cos \propto \quad (13)$$

an equation that must be satisfied when the dam reaches a position of equilibrium.

In equation (13) make $Y = .5X$, *i. e.*, suppose Z attached to the middle point of X, then we obtain

$$Z = .667 \frac{X}{\cos \propto} \quad (14)$$

The dam is shown in this position of equilibrium in Fig. 10, Plate A, the shaded triangles here and elsewhere in Plate A representing half the resultant opposing moments.

In equation (14) if

$Z = X$, $\cos \propto = .67$ and $\propto = 48° 11'$

$Z = 1.333 X$, $\cos \propto = .50$ and $\propto = 60° 00'$

From Fig. 9, Plate A

(14a) $H = X \sin \propto =$ height of crest of dam.

Assume width of foundation to be equal to the width of the dam lying flat, *i. e.*,

$$Z + Y \text{ or (when } Y = \tfrac{1}{2} X) \; Z + .5 X = .67 \frac{X}{\cos \propto} + \frac{X}{2}.$$

Denote the ratio $\dfrac{\text{height of crest}}{\text{assumed width of foundation}}$ by F or

$$F = \frac{X \sin \propto}{.667 \frac{X}{\cos \propto} + .5 X} = \frac{\sin \propto \cos \propto}{.667 + .5 \cos \propto} \quad (15)$$

$$\frac{d F}{d \propto} = \frac{6 (4 \cos^2 \propto - 4 \sin^2 \propto + 3 \cos^3 \propto)}{(4 + 3 \cos \propto)^2}$$

F will be a maximum when $\dfrac{d F}{d \propto} = 0$ or

placing $4 \cos^2 \propto - 4 \sin^2 \propto + 3 \cos^3 \propto = 0$

we get $\cos \propto = .635$ and $\propto = 50° 30'$

corresponding to maximum value of F. Substituting this value of α in equations (14), (14a) and (15) we get

$$\text{For } \alpha = 50^\circ\,30' \left\{ \begin{array}{l} F = .498 \\ Z = 1.05\ X \\ H = .77\ X = .73\ Z \\ H = .30\ (X + Y + Z) \end{array} \right.$$

Assume width of foundation equal to $DG = Z$.
Let

$$N = \frac{\text{height of crest}}{DG} = \frac{X \sin\alpha}{\frac{2}{3} \cdot \dfrac{X}{\cos\alpha}} = 1.5 \sin\alpha \cos\alpha \qquad (16)$$

N is a maximum when

$$\frac{dN}{d\alpha} = 1.5\,(\cos^2\alpha - \sin\alpha^2) = 0$$

or

$$\cos\alpha = \sin\alpha$$

or

$$\alpha = 45^\circ$$

Substituting this value in equations (14), (14a) and (15)

$$\text{We get for } \alpha = 45^\circ \left\{ \begin{array}{l} N = .75 \\ Z = .943\ X \\ H = .707\ X = .75\ Z \\ H = .290\ (X + Y + Z) \end{array} \right.$$

The functions F and N are represented in Fig. 3, Plate B.

TABLE OF PROPORTIONS.

Marshall's Bear-Trap Dam, No. 2, when $Y = \frac{1}{2} X$, and for No Back-water.

α	$\cos\alpha$	$\frac{X}{Z} = \frac{3}{2}\cos\alpha$	$\frac{Z}{X} = \frac{\frac{2}{3}}{\cos\alpha}$	$X + Y + Z = \frac{3}{2} X + Z$	$\frac{H}{X} = \sin\alpha$	$\frac{H}{Z} = \frac{\frac{3}{2}\cos\alpha}{\sin\alpha}$	$\frac{H}{X+Y+Z}$
30°	.866	1.299	.770	2.270 X	.500	.650	.220
35°	.819	1.229	.814	2.314 X	.574	.705	.248
40°	.766	1.149	.870	2.370 X	.643	.739	.271
45°	.707	1.0605	.943	2.443 X	.707	.750	.290
50°	.643	.965	1.037	2.537 X	.766	.739	.302
55°	.574	.861	1.161	2.661 X	.819	.705	.308
60°	.500	.750	1.333	2.833 X	.866	.650	.306
65°	.423	.633	1.576	3.076 X	.906	.608	.295
75°	.259	.389	2.574	4.074 X	.966	.376	.237

RATIO OF HEIGHT OF CREST TO TOTAL LEAF DEVELOPMENT.

Denote total length of leaves by $D = X + Y + Z$

when $Y = .5\ X$

$$D = 1.5\ X + Z$$

and

$$U = \frac{H}{D} = \frac{H}{1.5\ X + Z} = \frac{6 \sin \propto \cos \propto}{9 \cos \propto + 4}$$

$$\therefore \frac{d\ U}{d \propto} = \frac{6\ (9 \cos^3 \propto + 8 \cos^2 \propto - 4)}{(9 \cos \propto + 4)^2}$$

U becomes a maximum when $\propto = 56° \ 18'$.

b.—WHEN BACKWATER RISES TO *E*.

In this case the moment equation (2) is opposed by the moments in equations (4) and (6). Expressing this condition algebraically we have for equilibrium (position shown in Fig. 11, Plate A).

$$.167\ X^3 \,.\, w \,.\, \sin \propto = Z \,.\, Y \,.\, w\ (X - Y) \sin \propto \cos \propto + .167\ w \frac{h^3}{\sin^2 \propto} \tag{17}$$

In (17) let $Y = .5\ X$ and $h = Y \sin \propto$. Hence by substitution and reduction we get

$$.167\ X^3 \,.\, w \,.\, \sin \propto = Z \,.\, Y \,.\, w\ (X - Y) \sin \propto \cos \propto + .167\ Y^3 \,.\, w \,.\, \sin \propto$$

or

$$.167\ X = .25\ Z \cos \propto + .02083\ X$$

or

$$.1458\ X = .25\ Z \cos \propto$$

or

$$Z = \frac{.5833\ X}{\cos \propto} \tag{18}$$

and

$$\cos \propto = \frac{.5833\ X}{Z} \tag{19}$$

$\therefore$ In equation (19) if $Z = X$; $\cos \propto = .5833$; $\propto = 54° \ 09'$

In equation (19) if $Z = 1.167\ X$; $\cos \propto = .500$; $\propto = 60° 00$.

In the dam calculated to rise to 45° without backwater we have (*see table*)

$$Z = .943\ X. \quad \text{Therefore } \frac{X}{Z} = 1.0605$$

and when backwater rises to E

$$\frac{7}{12} \frac{X}{Z} = \cos \propto = \frac{7.4235}{12} = .6186. \quad \text{Therefore } \propto = 51° \ 47';$$

$$\sin \propto = .7867.$$

and

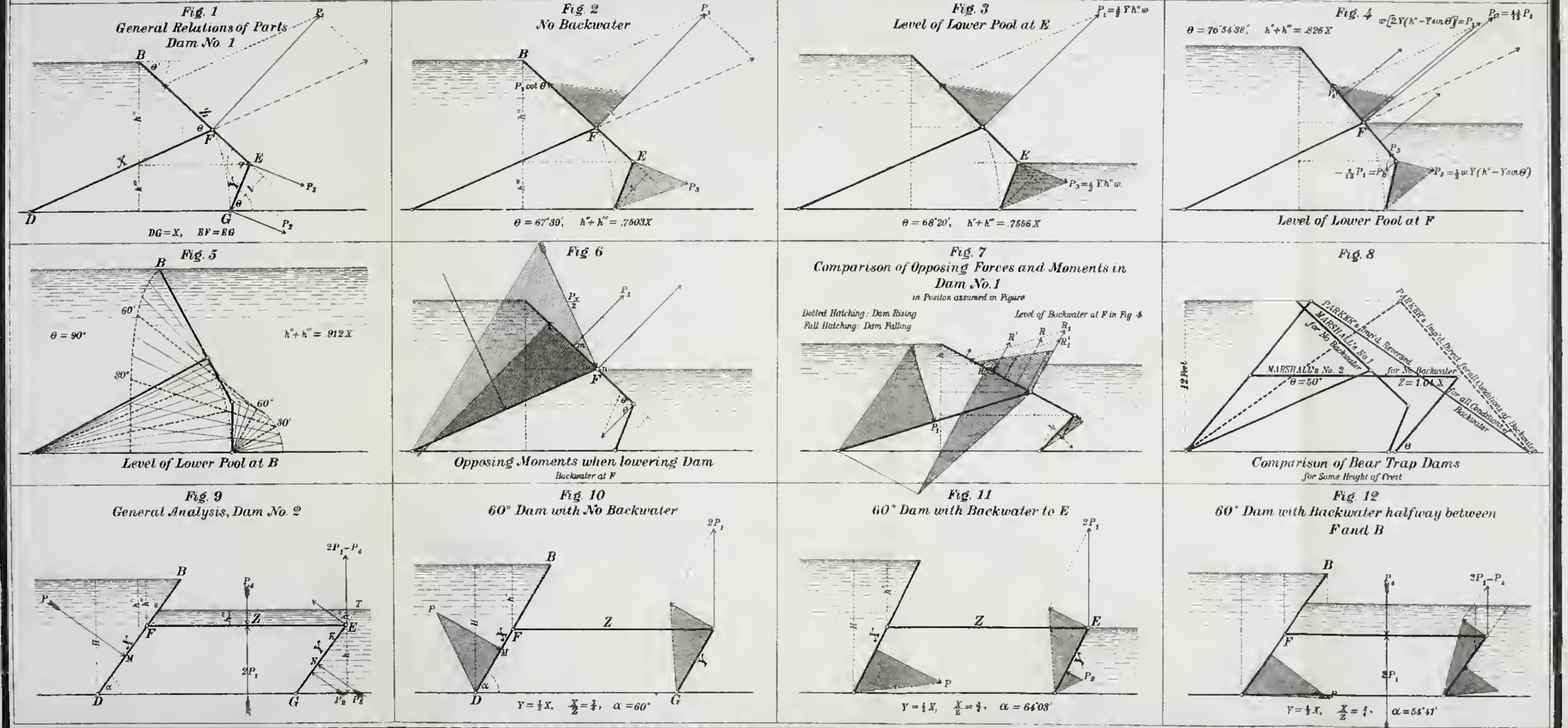
$$H = X \sin \propto = .786\ X = .833\ Z.$$

In 60° dam

$$\frac{X}{Z} = .75; \cos \propto = (.5833)\ (.75) = .4375; \propto = 64° \ 03'$$

THE MARSHALL DAMS.

Plate A.



THE MARSHALL DAMS.

Plate B

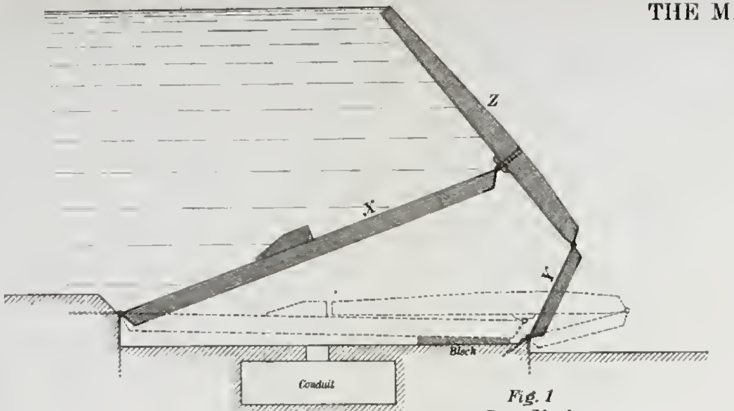


Fig. 1
Dam No 1

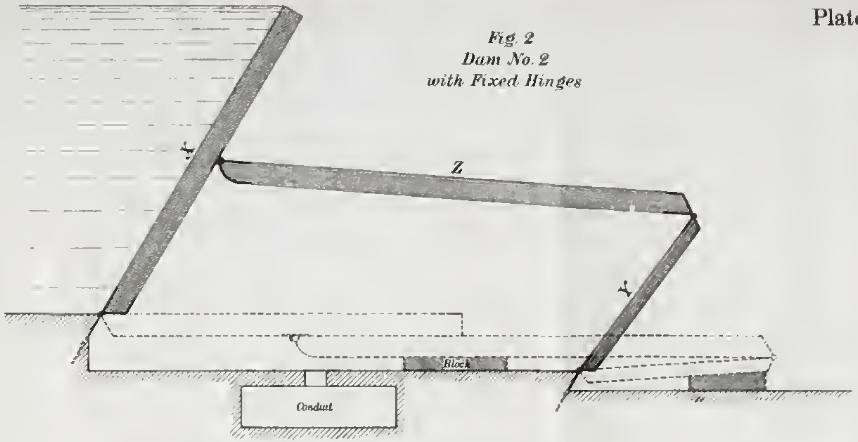


Fig. 2
Dam No. 2
with Fixed Hinges

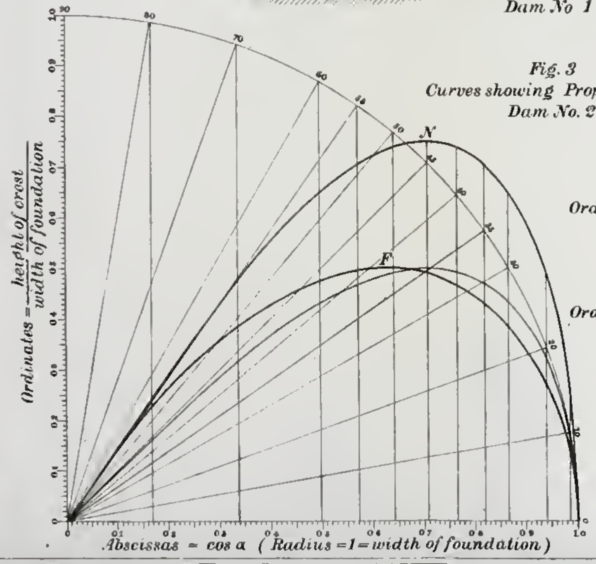


Fig. 3
Curves showing Proportions of
Dam No. 2

Ordinates of Curve F $= \dfrac{\textit{height of crest}}{\textit{width of foundation}}$, *when*

width of foundation $= Z + \frac{1}{2}X$

Ordinates of Curve N $= \dfrac{\textit{height of crest}}{\textit{width of foundation}}$, *when*

width of foundation $= Z$

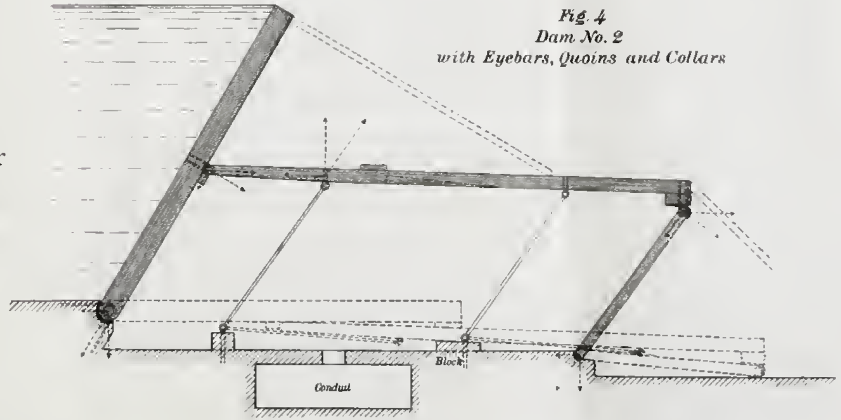
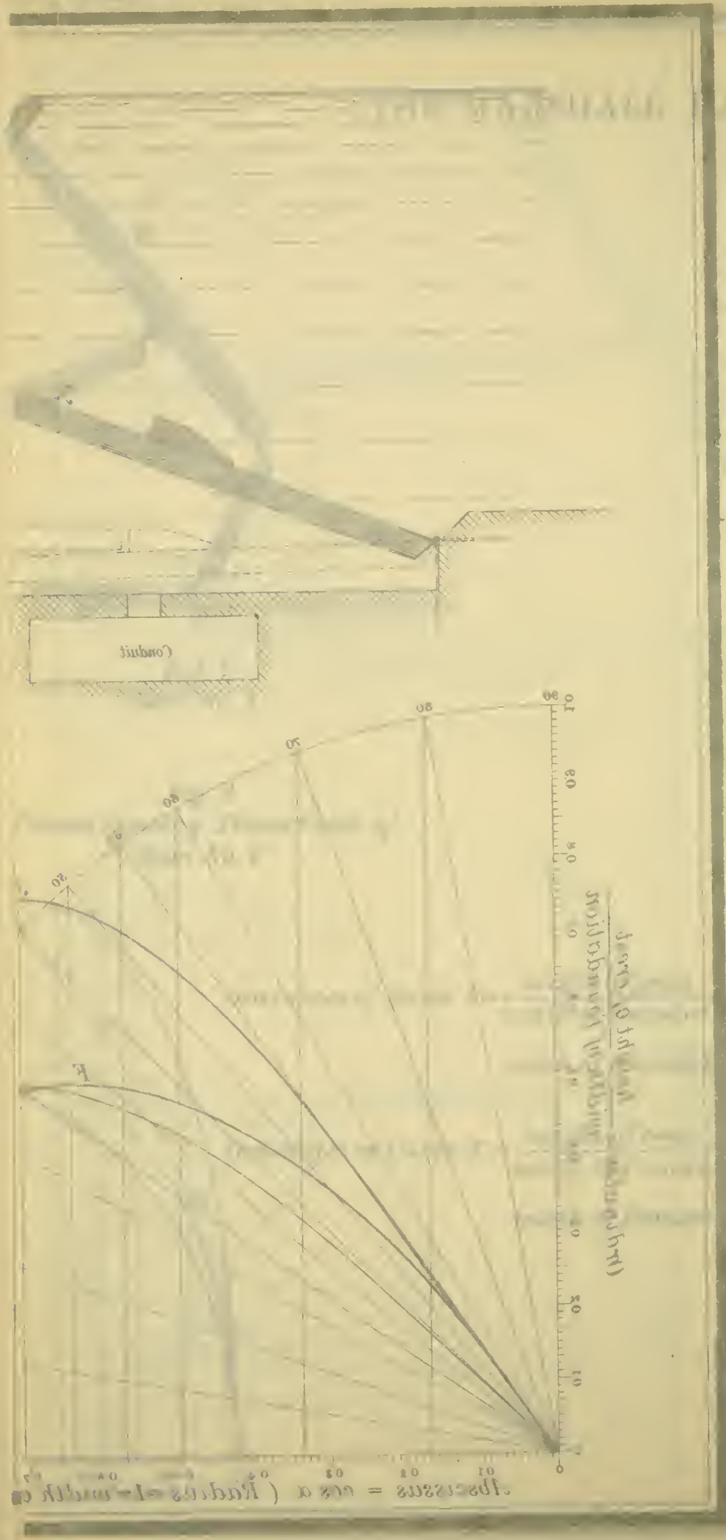


Fig. 4
Dam No. 2
with Eyebars, Quoins and Collars



c.—WHEN BACKWATER RISES ABOVE E.

(Position of equilibrium shown in Fig. 12, Pl. A.)

In this case the sum of the moments derived from P and P_4, equations (2) and (10) will be opposed by the sum of the moments derived from 2 P_1 and P_3, equations (4) and (8). Expressing this condition algebraically we must have for equilibrium

$$.167\, X^3 . w . \sin\alpha + Z . Y . m . w . (X - Y) \sin\alpha \cos\alpha$$
$$= \qquad (20)$$
$$Z . Y . w (X - Y) \sin\alpha \cos\alpha + .167 [Y + m (X - Y)]^3 w . \sin\alpha$$

Placing $Y = .5\, X$ and reducing we obtain, omitting factor

$X^2 . w \sin\alpha$:

$$.167\, X + .25\, m . Z . \cos\alpha = .25\, Z \cos\alpha + .020833\, X (m + 1)^3$$

or

$$\cos\alpha = \frac{X}{Z}\left(\frac{8 - (m + 1)^3}{12\,(1 - m)}\right) = \frac{X}{Z}\left(\frac{7 + 4\,m + m^2}{12}\right) \qquad (22)$$

If $m = O$ or backwater only as high as E, $\cos\alpha = \frac{X}{Z} \cdot \frac{7}{12}$, the same as in equation (19).

If $m = 1$ or backwater is level with the crest

$$\cos\alpha = \frac{X}{Z} \cdot \frac{12}{12} = \frac{X}{Z}$$

but making this supposition $m = 1$ in equation (20) we obtain an identical equation indicating the dam to be in a condition of indifferent equilibrium, *i.e.* $\frac{X}{Z}$ is a limiting value of $\cos\alpha$ approached as the backwater gradually rises.

Between the limits $m = O$ and $m = 1$, $\cos\alpha$ increases in value and is always positive.

For $\frac{X}{Z} = 1$:

$m = 0$	$\cos\alpha = \frac{7}{12}$	and $\alpha = 54^\circ\ 09'$
$m = 1$	$\cos\alpha = 1$	and $\alpha = 00^\circ\ 00'$

or the dam will rise to 54° 09′ when backwater level reaches E, Fig. 9, and on further rise of the backwater will lower gradually, reaching its flat position as the backwater level reaches the crest of the dam. This is true only under the supposition that the levels of the upper and lower pools follow the dam in all its positions, that no water pours over the crest, and that there is perfectly free communication between the upper pool and the hydraulic chamber. In an actual dam the crest would lower only until submerged by the backwater, the lowering would be assisted by the current and water from the upper pool, and resisted by the forces opposing the movement of the water out of the hydraulic chamber.

In equation (22) for $\frac{X}{Z} > 1$ the highest position of dam will be less than 54° 09′, and it will, under conditions stated above, fall flat before $m = 1$, or before backwater reaches the crest.

If in equation (22) $\frac{X}{Z} < 1$ the highest position of the dam will be at an angle, whose cosine is less than $\frac{7}{12}$, *i. e.*, $\propto > 54° \; 09'$, and the dam will not fall flat when backwater reaches the crest, but will attain its state of indifferent equilibrium at some angle whose cosine is less than 1, its value depending on the ratio, $\frac{X}{Z}$.

Consider the dam proportioned to rise 60° with no backwater; in this $Z = \frac{4}{3}X$, or $\frac{X}{Z} = \frac{3}{4}$ and $\cos \propto$ (for no backwater) $= .5$;

$$\text{Therefore } \propto \; = 60°$$

For backwater as high as *E*, Fig. 9, Plate *A*, $m = 0$ in equation (22), and

	$\cos \propto \; = \frac{3}{4} \cdot \frac{7}{12} = \frac{7}{16}$	$\therefore \propto \; = 64° \; 03'$
If $m = \frac{1}{10}$	$\cos \propto \; = \frac{3}{4}\,(.6175) = .4647$	$\therefore \propto \; = 62° \; 19'$
If $m = \frac{2}{10}$	$\cos \propto \; = \frac{3}{4}\,(.6533) = .4900$	$\therefore \propto \; = 60° \; 39'$
If $m = \frac{3}{10}$	$\cos \propto \; = \frac{3}{4}\,(.6908) = .5181$	$\therefore \propto \; = 58° \; 48'$
If $m = \frac{5}{10}$	$\cos \propto \; = \frac{3}{4}\,(.7708) = .5781$	$\therefore \propto \; = 54° \; 41'$
If $m = 1.0$	$\cos \propto \; = .7500$	$\therefore \propto \; = 41° \; 25'$

CASE II.—DAM FALLING.

Hydraulic chamber in communication with lower pool only.

In this case it is evident that the resultant of all the forces acts to depress the dam until the crest is submerged, after which the weight of the dam alone must be relied upon in still water for further lowering. A mathematical discussion is unnecessary,

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V. Bear-Trap Weirs.

By W. A. Jones, Lieut. Colonel, Corps of Engineers, U. S. A.

The new form of bear-trap weir is a very interesting addition to the repertoire of the engineering profession. It unfolds wide vistas before us. I will here touch upon one or two. At Sandy Lake dam, Minnesota, the United States government has made an application of it as a lock gate, the first of its kind, I believe. The lock has been completed since the fall of 1895. The gates operate freely under a head of between one and two inches. This easy action seems to settle the question of the adaptability of this form of weir to this purpose. Except under the re-

versed conditions, no auxiliary raising power is needed. The upper gate can be raised, when a boat is in the lock, going down, by lowering the lower gate a little, just enough to create a current over the upper. There is no lift wall. I think it may be safely announced that the bear-trap weir is available as a lock gate in many instances, particularly for gates to be operated under reversed head. For high lifts, a secondary set of anchor chains along the line of center of pressure will avoid cumbersome construction. For narrow locks with high lifts there may be cases where this form will take up too much of the length of the lock. It is of simple construction and design, easy of operation, puts no strain on side walls, requires no machinery, and is accessible for repairs in the ordinary way. It will ordinarily keep itself clear of sediment, and in extreme cases the feed and exhaust water can be specially handled so as to create a swirl which will keep it clear. It furnishes a reversible gate to enable tide locks to be operated at all stages of tide.

The gates at Sandy Lake dam have since been operated every day except two, during the whole of a Minnesota winter. It has been a mild winter, on the whole, with spells of extreme severity. They have been operated at temperatures below 30°F. without the aid of steam. At very low temperatures ice will form inside along the contact of gate and wall. A light, portable steam boiler furnishing steam through a hose and small nozzle removes it quickly, and is useful in clearing ice from any sort of gate which has to be manipulated in winter. This feature will enable locks to be operated in any low temperature likely to occur in places where canals are used. It will make it possible to extend the period of navigation several days for all canals subject to winter closing. And for some short canals there seems to be a reasonable certainty of keeping them open for navigation all winter. By keeping a current running through, there can be maintained a channel of open, or thinly iced, water through which boats could pass, while the locks can be kept open by operating the gates. With the facts now before us, it certainly looks as though the navigation of the Great Lakes might be made continuous. The principal difficulty would probably be found in Detroit River. But there is such a great volume of water flowing through that the concentration of velocity in an open or thinly iced channel would probably prevent the formation of very thick ice.

Again, this form of weir enables the control of the level of ponded water. Now it is a far cry from a mill pond to the great inland seas of America, and yet the time has come for consideration of the question whether their broad surfaces may not be placed at a desired level and the same maintained, independent of climatic conditions, by the use of great dams discharging over the new bear-trap weir.

The discussion of Mr. Powell's paper seems to have developed into a symposium on

and it has fallen to my lot to present the bear-trap forms designed by Mr. Lang and myself. It has seemed to me that a great step forward was taken when Mr. Lang detached the intermediate leaf of the Parker form and substituted chains for the anchorage. This abolished the friction of two hinged joints acting under a forced parallelism with the two floor joints, and relieved the system of a lot of adverse pressures by folding the intermediate leaf outside of the hydraulic chamber instead of inside. The evolution of the present form seems to have been:

I.

Two leaves folding down, one upon the other, free at upper ends.

II.

Connecting the two leaves of (I) with an intermediate leaf, folding *into* the hydraulic chamber.

III.

Detaching the lower joint of the intermediate leaf of (II) and allowing it to fold down *outside* the hydraulic chamber by sliding upon the upper leaf, and connecting the crests of the upper and lower leaves by chains. Other forms have been designed, but I am not yet satisfied they have developed any marked advance on these three.

By the term "Bear trap weir" is meant a rising and falling weir formed of two or more leaves joined together and to the floor of the waterway, the said leaves being raised by introducing water beneath them from the upper pool, and lowered by exhausting said water into the lower pool.

The Lang form is III, as above. The downstream leaf is called the "lower" leaf. The upstream leaf, the upper, and the intermediate leaf, the "idler." The feed and exhaust of water through the hydraulic chamber formed by the leaves and waterway walls may be through the floor or side walls. The manipulation of the weir (I will use the term "gate" hereafter) is simplified by the use of one valve. I have designed a cylinder valve which enables the operation of the gate by one motion of the operator. It is an application of the 3-way cock. By setting the valve so that the water which runs into the hydraulic chamber equals that which runs out, the gate will stand indefinitely at any desired height. Two positions of the valve effect this. One, which makes the opening of the outlet port equal that of the inlet port, varied by the effect of leakage. The other where the outlet valve is wholly closed, or closed so as to offset the leakage, and hold a fixed quantity of water in the chamber. In the later case there is no waste of water, except leakage. Plain slide valves

can often be used. Where they carry much pressure they should be on roller bearings of gun metal. The cylinder valve can be balanced so as to be of easy manipulation under great pressures.

Mr. Lang has designed sliding props to hold the gate in the up position for repairs. Where there is no backwater the gate can be emptied easily. In all important structures, provision should be made for temporary coffer-dams above and below, to be used when repairs are necessary. These can be simple and inexpensive.

There are now completed and in successful operation gates of this form at the following places:

SAINT CROIX RIVER, AT NEVERS, WISCONSIN.

1 gate, 80′ length of crest, 16′ rise.
1 " 24′ " " " 16′ "
1 " 20′ " " " 16′ "

Completed in winter of 1890–91.

MISSISSIPPI RIVER, AT LITTLE FALLS, MINNESOTA.

1 gate, 60′ length of crest, 7′ rise.

Completed in winter of 1891–2.

CHIPPEWA RIVER, AT LITTLE FALLS, MINNESOTA.

1 gate, 58′ length of crest, 12′ rise.
1 " 14′ " " " 12′ "

Built in 1892–3.

CHIPPEWA RIVER, AT CHIPPEWA FALLS, WISCONSIN.

1 gate, 80′ length of crest, 6′ rise.

Built in 1893–4.

SANDY LAKE DAM, MINNESOTA, U. S. GOVERNMENT.

1 gate, 11′ length of crest, 12′ rise.
2 " 40′ " " " 13′ "

Through a misapprehension of my instructions, the upper leaves of the Sandy Lake lock gates were made lighter than water. This will cause them to fail at some stages, but the difficulty will be remedied at a convenient time. Three more are in course of construction on the Mississippi River at Minneapolis, Minn., in the new power dam of the Minneapolis Mill Company. They are 50′ length of crest and 16′ rise.

In comparing different forms, let the lengths and relations of the leaves be properly adjusted to cover the same conditions. Then, in each case, make a discussion of the values of the operative pressures under the conditions of head, varying or otherwise, and for a number of positions between the up and down limits. Note the relation between the

available and the useful pressures and how much of the former is non-effective. Note particularly the values of the useful pressures at the positions of minimum effect. In the Parker form this position is reached gradually in the final stages of depression, where a sort of dead point is reached which allows a very appreciable movement to take place without any corresponding lowering of the gate. In the Lang form it is approached gradually in lowering from the full raised position to that where the angle between the idler and lower leaf becomes a minimum. Here the friction at the toe of the idler may become sufficient to lock the movement, unless the parts are properly adjusted.

The inherent virtue of this system of weir is that it will carry a great head, and lower, under simple and easy control, *against all of that head.* It may be described as a device which enables a leaf to be rotated upwards on a floor axis by means of the pressure from the head, and, at the same time, to enable that leaf to be lowered *by the pressures from the same head.* It is possible, at all times, to release all upward pressures from the lower leaf, leaving nothing acting on the gate excepting the downward hydraulic pressures increased by its Sp. G. in excess of that of water. For operation under delicate shades of pressure friction becomes a principal item, and the less the number of joints where friction may arise the better.

The making of wet operative models will be attended with difficulty unless the parts are of metal and glass. They are apt to fail from causes not effective on a full-sized structure. Leakage and friction become factors wholly out of proportion to what they actually are in practice.

ANALYSIS OF THE PRESSURES.

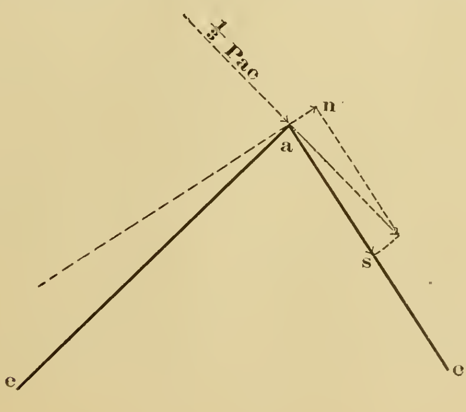
Let x represent the length, bd, of the upstream leaf (Plate I, Fig. 1), y that of ac, the downstream leaf, $y - x = ad$, the chain connection. Let ae be the idler. Sp. G. of the moving parts in water $= 1.0$. Friction $= 0$. Head $= h''$, under the assumption that it is concentrated at a by a stop plank. Let the hydraulic chamber be connected with the upper pool and cut off from the lower. All pressures to the left of a being balanced, as also those on bd to the right of a, it is evident that any positive value for h'' will create an operative upward pressure. The full effect of the pressure from h'' will act from a to c on ac. As this is the position of minimum effect of the raising forces, no further consideration is necessary. Conversely, connect the hydraulic chamber with lower and cut off the upper pool and the pressure from h'' will act with great efficiency in holding the gate down. Practically, a very small head will operate the gate. The joints at a and d being relieved from any necessity for moving parallel to each other and to those at b and c, the friction from these sources will be small.

Let Fig. 2, Plate I be the up position of the gate. Assume ac standing at an angle of 45° with bc and ab at right angles with it.

$$ad = y - x$$
$$de = z$$
$$ae = y - x + z$$

In this position, with hydraulic chamber connected with upper and cut off from lower pool, there is no unbalanced pressure on ae and be. That from h'' is wholly on ac, and so long as its moment is sufficient to equal or exceed that of the effective weight of all the moving parts the gate will stay up. As before, a very small head will suffice. Now change the valves so that hydraulic chamber is connected with lower and cut off from upper pool. The water in it will run out until its level is same as that of lower pool. This releases ac from all pressures which held it up and brings into play the whole weight of the structure above the level of lower pool. The whole pressure from h'' is transferred from the under side of ac to the upper side of aeb. It tends to rotate ae downward about a, and bd downward about b. Everything tends to move the system downwards except the pressures carried at a and b, and the friction at e. Any difference of level between upper and lower pools will create relatively the same effects.

By the term "critical" position is simply meant that position where the downward tending forces are a minimum. By gradually lowering the gate it will be seen that the angle at a, between ae and ac, gradually decreases until a minimum is reached at about 5° of depression of ac, and thereafter increases to 180°, nearly, as the gate descends. Fig. 2, Plate 1, shows this position. Whatever water flows over the crest while lowering adds its dynamic effect on the lower leaf to the downward forces. We will assume none passing. In this position we will have on ac and aeb the same conditions as before, except that that portion of the pressure on ae, which is carried at a, is decomposed thus:



One component, *as*, goes down *ac* with no moment. The other, *an*, acts tending to rotate *ac* upward against the downward tending forces brought to the same point of application by the chain *ad*. In case the conditions render it necessary, *an* can be abolished as an opposing force by slightly increasing the length of *bd* and *ae*.

One part of the down pressure on idler and upper leaf is transferred after decomposition, to *a* along the line *ad*. Fig. 3, Plate I. Here it is resolved again, the normal, or moment component, tending to rotate the lower leaf. This component is decomposed, one part going down *ae* to *e*. Here it becomes decomposed, the normal component creating friction and tending to rotate the upper leaf, the other tending to slide the point of *ae* along the surface of the upper leaf. In Fig. 3 I have shown three positions of *ae*, corresponding to different values of the angle *eac*, two less than 90°. Resolving the force at *e*, it will be seen how the sliding component decreases and the friction component increases as the angle *eac* decreases. The friction component is practically rendered ineffective by introducing rollers at *e*.

As the angle at *a* decreases, the sliding component at *e* decreases until it equals the friction created by the friction component. At this point, the toe of the idler being unable to slide, the downward movement will cease. When *ae* is at right angles with *bd* the sliding component becomes 0. By giving *ae* such length as to make it meet *bd* at 45° the two components become equal. Now if we remove most of the friction by making it rolling, it will be evident that the point *e* will freely slide. By constructing the opposing forces at *a* under this assumption, it will be seen that there is a sufficient preponderance of downward pressure. Hence this may safely be assumed as giving a minimum value for the angle *eac*.

A general analysis of the relations between the pressures and lengths of the moving parts involves many elements, and will be complicated. I will only attempt one, based on certain assumptions which are either correct or nearly so. Let *ac*, Fig. 2, Plate I, be the lower leaf, standing on an angle of 45° with the horizontal; *ab*, the upper leaf and chain at right angles. Let *Ca'd'b* be the most unfavorable position in descending. Take it so that *a'd'* prolonged passes through *h*, the middle of *bc*. Assume *a'e* on the chord *a'a''*, also *ac* as unity. $oa' = \tan oca'$, oc sec. $oh = oc - \frac{1}{2}\, bc$, $< a'o\ c = 90° - < oa'c$, $bd = bh$, $de = ab - bd$, $< oa'a''$ is known. From $a'o$, oh, and included angle deduce $< oa'\ h < ea'd' = < oa'h - < oa'a''$. From ea', $a'd'$ and included angle, get ed'. Hence be,

Let $< ea'd' = \theta$

and $< ea'c = \theta'$

$\theta' = \theta + < da'c$

The critical conditions will be for small values of h'', the head, or difference of level. For such the pressure on $ea' = P_1 = ea' \times h'' w$, w being the weight of a cubic unit of water. Its moment component around b will be transferred to d', and its component along the chain $d'a'$ will be

$$P' f(\theta)$$

Similarly, the component from be which acts along $d'a'$ will be

$$P'' f(\theta)$$

Let $P' + P'' = P_d$

The moment component around c applied by the chain at a' will be

$$P_d f(\theta)$$

One third the pressure on ea' is carried at a'. When $\theta + \angle d'a'c = 90°$, it will have no moment about c. When it is greater than 90° the moment component will be added to $P_d f(\theta)$. When the angle is less than 90°, the moment component will be applied at the same point but will act in opposite direction. It will be

$$\tfrac{1}{3} P_1 f(\theta)$$

Equate the values of these opposing forces, using θ as the unknown quantity. Substitute $\theta' - \angle d'a'c$ for θ and solve for a minimum value of θ' by differentiation. The corresponding value of ea' will result.

TO DESIGN THE STRUCTURE.

The reference of the floor of the waterway and that of the surface of the upper pool will be known Fig. 2, Plate I. Let bc be the floor and ah the height of the upper pool. From a draw ab and ac at right angles, ac will be the lower leaf in position and length. ab, the upper leaf and chain connection in preliminary position and length. From b as center draw arc with radius bh to cut ab in d. d is the link point for bd and ad to fold upon. bd will be the upper leaf and ad its connection with lower leaf. An angle of 45° may not be the best for lower leaf to stand upon, but it is found in practice to be very near it, and it is adopted for the sake of simplicity. It will be observed the $\angle eac$ is a right angle. For the first 5° of descent this angle decreases to a minimum and thereafter increases through the whole descent. The broken lines show, diagrammatically, the structure in this position. Assume $a'c$ on the cord $a'a''$ as the length of the idler. This will be sufficient in most cases. To give upper leaf and idler such length as will make the angle at $a' = 90°$ very nearly, and abolish the adverse component at a': Rotate the system to the down position as shown. Move b to the left a distance equal to $\frac{1}{10}$ ac. Make the idler $= a'b'$. This completes the design so far as position and lengths of the moving parts are concerned. c and b

are the axes of the floor hinges. The angle *eac*, between lower leaf and idler, will not become less than 90° in the movement of the gate, and all the unbalanced forces will act positively in raising or lowering the gate.

PRACTICAL CONSIDERATION.

I will indicate some practical points developed by our experience:

No grating will keep a certain amount of finely divided floating matter from getting into the hydraulic chamber. If the floor hinge joints are on the upper corner of the leaves, an angle will result between the leaves and floor walls and this floating stuff may gradually get so packed in it as to prevent leaves from going clear down.

Ports and flumes should be of ample size.

Iron work should be protected from the oxidizing action of water. Moisture seems to be a necessary adjunct of oxidation of iron at ordinary temperatures. There is more or less oxygen, possibly in dilute form, in water, and hence iron rapidly oxidizes in it. The use of copper or zinc plating or paraffin paint is suggested. Coating by dipping in a melted alloy of zinc and tin and bismuth is also suggested. Friction rollers, particularly.

In wooden gates, to counteract the effect of swelling, they should be nearly constructed, and then allowed to thoroughly soak before final parts are added.

Reciprocating valves are not necessary, except, a single valve is quicker and simpler in operation.

To control excessive pressures at any point of a controlled opening, use small "bleeder" valves.

To keep hydraulic chamber reasonably free from sediment, adjust inlet and outlet ports so as to create a swirl in it.

To keep valves and chamber free from ice, leave valves open slightly so as to keep up a motion of the water. In case ice forms on contact between leaves and walls, remove it with a steam jet.

The joints between ends of leaves and the side walls need not be tight in most cases. A play of one inch can be freely allowed where leakage is not of consequence. In the up position, leakage can be pretty well stopped by letting the lower leaf rest against stops on the side walls. If it is desired to pack the joints in all operative positions, a wedge-shaped strip, pressed into the joint by springs, will do it. Rubber flaps and tubes are found inoperative. They create too much friction.

REVERSIBLE WEIR WITH SHORT BASE.

There will be cases where the length of the floor of the waterway occupied by the gate must be as small as possible. The form shown in Plate II is designed to meet them. The link members fold backwards

towards the upper floor hinge and are braced by the chain and rod connections BD and CD. In cases where the overfall is great and HC is left exposed, or where floating matter passes over the crest, a fender can be placed at EH. On account of the moments of forces on CF around E acting in opposition the gate will reach its full height without shock. Theoretically, EF can be made longer than as shown. In the raised position the system is perfectly rigid and strong. Any difference of level will lower it. Assuming the submerged Sp. G. $= 1.0$ a head sufficient to create pressures in excess of the friction, and weight of exposed parts will raise it. Any attempt at establishing a general relation between the lengths of the section parts by analysis will be unsatisfactory and result in an approximation which can be reached some other way, unless the dynamic effect of the water passing over the crest F is taken into consideration. This will introduce serious complications in the analysis. These remarks apply to any form of bear-trap. The rod CD is introduced to complete the link $AHCD$. The chain BD locks the system. P and P' are pillow blocks.

The following procedure is recommended for designing this form. Let AD' be the floor of the waterway and $H = F'D'$ the height of the pond upon it. $C'D'$ must be assumed. Moving C' downwards will reduce the base RS, in its ratio to H. Moving it upwards will increase it. Local conditions will largely affect the assumption. It will be an advantage to hold BC beneath the level of the lower pool. Having $C'D'$, $E'C'$ may ordinarily be assumed equal to $E'F'$. Now draw FE CD' vertical. Make $CD' = C'D'$ and $CE = EF$. Draw BC horizontal $= CE$. Draw AB and CD parallel and to the floor so that B will rotate down to D. Describe an arc to the floor, from D with radius CD. Describe ark CK from E. Now determine the thickness of the members AB, BC, and CF from a consideration of the strains to which they will be subjected. Make them of equal thickness for simplicity. Twice that thickness above AD' draw GG' parallel to it. On this line find the point G equidistant from the arcs drawn from E and D as centers. Draw GE and give this member same thickness as the others, for simplicity. Draw in the other members, showing thickness and articulate with hinge joints as shown. This articulation is now such as will fold down neatly. In this down position, when pressure is introduced in the hydraulic chamber, that which comes upon the upper side of CE will just about balance that which comes upon the under side of BC and that upon AB is the active force in raising the gate. As the gate raises, the pressure on EC becomes less in proportion to that which comes on BC and the lifting effect increases but is gradually offset by the pressure on EF, thus relieving the shock. Let us compare the forces with the assumed proportions. See Fig. 4, Plate I. All lines to scale, no backwater.

$h_1 = 14'$, $h_2 = 12'$, $h_3 = 9'$, $h_4 = 3'$
$ab = 5'.5$, $bc = ce = ef = b'$

$$P_1 = ab \times h_1 w = 4812.5 \text{ lbs.}$$
$$P_2 = bc \times h_2 w = 4500 \quad \text{“}$$
$$P_3 = ce \times h_3 w = 3375 \quad \text{“}$$
$$P_4 = ef \times h_4 w = 1125 \quad \text{“}$$

The strains concentrated at c are assembled graphically upon cs. Their moment effect, em', around g as a center, will be opposed by em, that of $P_4 + \frac{1}{3}P_3$, $em = 2250$ lbs., $em' = 2800$ lbs.

Let $x = ab$, $y = bc = ce = ef$, $\theta = \angle baa' = 45°$, $\theta' = \angle gec$.

Normal pressure at	b	from	$ab = bo$	$=$	$\frac{1}{3}h_1 wx$
“ “ “	b	“	$bc = bo_1$	$=$	$\frac{1}{2}h_2 wy$
“ “ “	c	“	$bc = bo_1$	$=$	$\frac{1}{2}h_2 wy$
“ “ “	c	“	$ce = co_3$	$=$	$\frac{2}{3}h_3 wy$
“ “ “	e	“	$fec = eo_4$	$=$	$\frac{1}{3}h_3 wy + h_4 wy$

Take the moment around a. The rotating component of P_2 at b is:

$$\tfrac{1}{2}P_2 \cos\theta = \tfrac{1}{2}h_2 wy \cos\theta$$

Add this to $\frac{1}{3}P_1$ for the whole rotating force:

$$\tfrac{1}{3}h_1 wx + \tfrac{1}{2}h_2 wy \cos\theta = \tfrac{1}{3}h_1 wx + 2h_4 wy \cos\theta$$

The rotating force at c is:

$$4\, h_4 wy \cos\theta$$
$$cs = \tfrac{1}{3}\, h_1 wx + 6\, h_1 wy \cos\theta$$

Its component along cf is:

$$\frac{\frac{1}{3}\, h_1 wx + 6\, h_4 wy \cos\theta}{\cos\theta} = \frac{h_1 wx}{3\cos\theta} + 6\, h_4 w\, y$$

Decompose at e for the moment component around g, which is:

$$em' = \left(\frac{h_1 wx}{3\cos\theta} + 6\, h_4 wy\right)\sin\theta' \qquad (1)$$

The moment component of the opposing force is:

$$em = 2h_4\, wy \cos\theta' \qquad (2)$$

Equate (1) and (2):

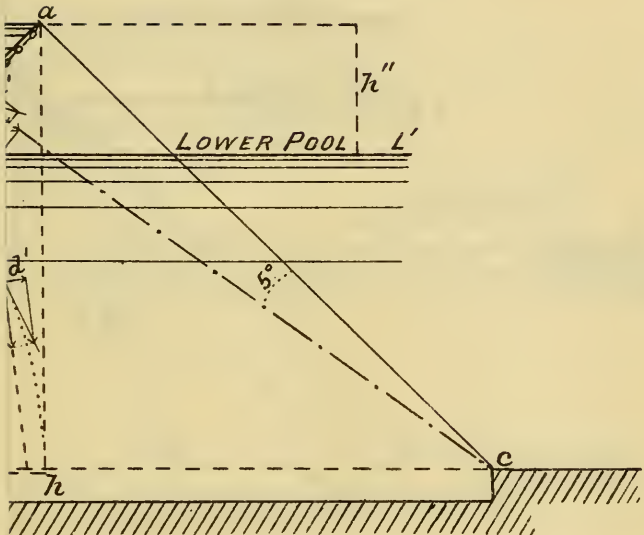
$$\frac{h_1 \tan\theta'}{3\cos\theta}\, x + \left(6h_4 \tan\theta' - 2\, h_4\right) y = 0 \qquad (3)$$

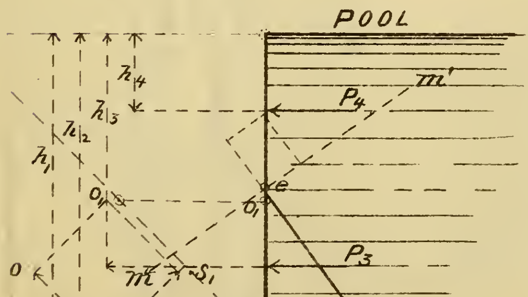
As this discussion ignores the acting weight of the moving parts, and the dynamic and static effects of the water falling over the crest, it is not considered satisfactory.

A LONG WEIR.

As a summing up of the experience so far gained I present on Plate III, a design for a bear-trap weir 600′ long with a rise of 16′. To

PLATE 1.





BEARTRAP WEIRS

(JONES.)

PLATE 1.

Fig. 1

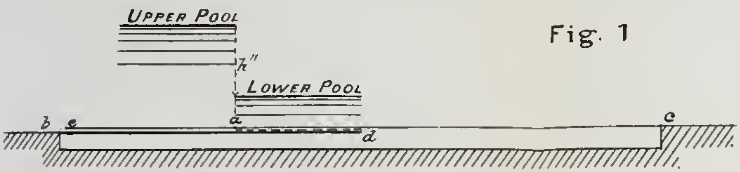


Fig. 2

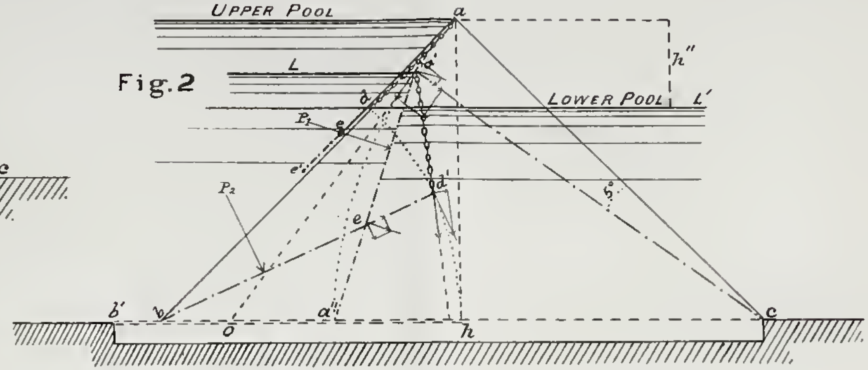


Fig. 3

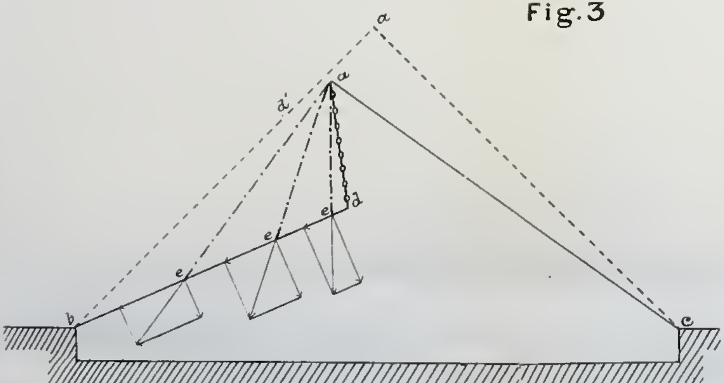
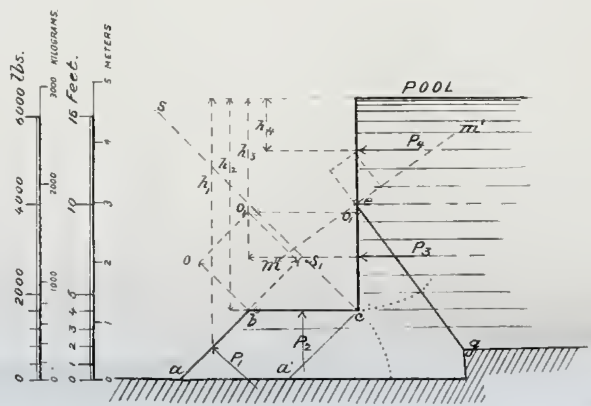
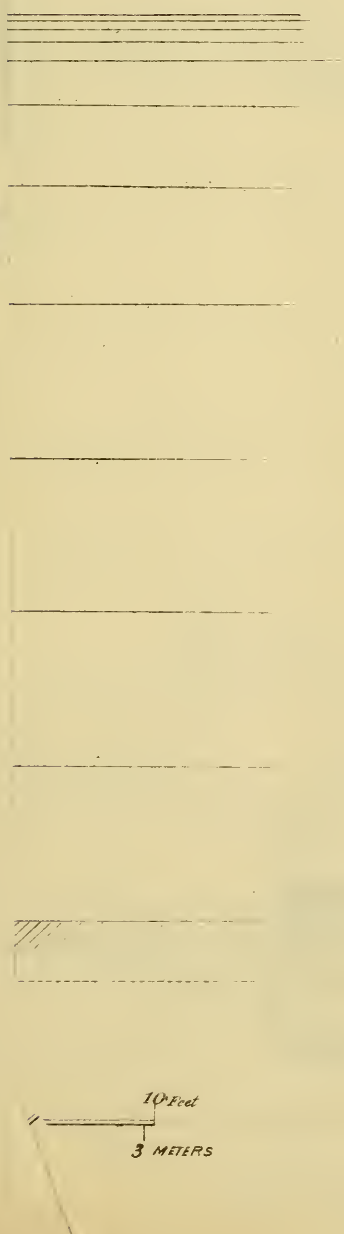


Fig. 4

4



WEIRS.

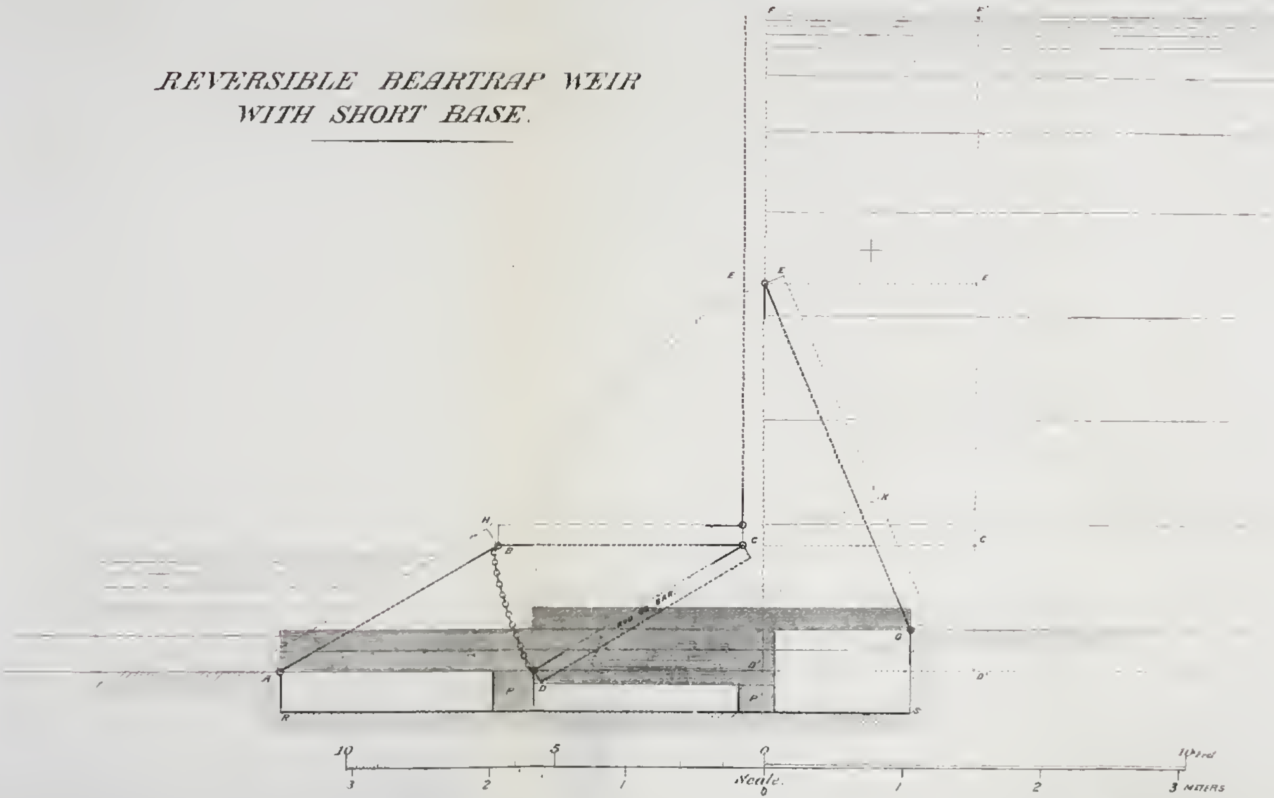


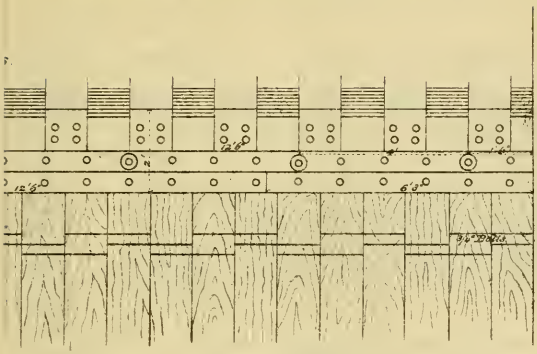
BEARTRAP WEIRS.

(JONES.)

PLATE II.

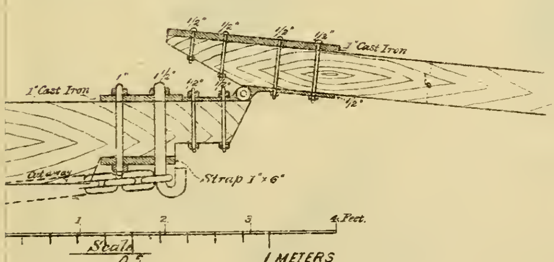
REVERSIBLE BEARTRAP WEIR WITH SHORT BASE.





*Lines of Bolts 2'x 3/4" Clear Across At Middle Near
, and Bottom. Timbers of Leaves and Idler Grooved for
Tongue.*

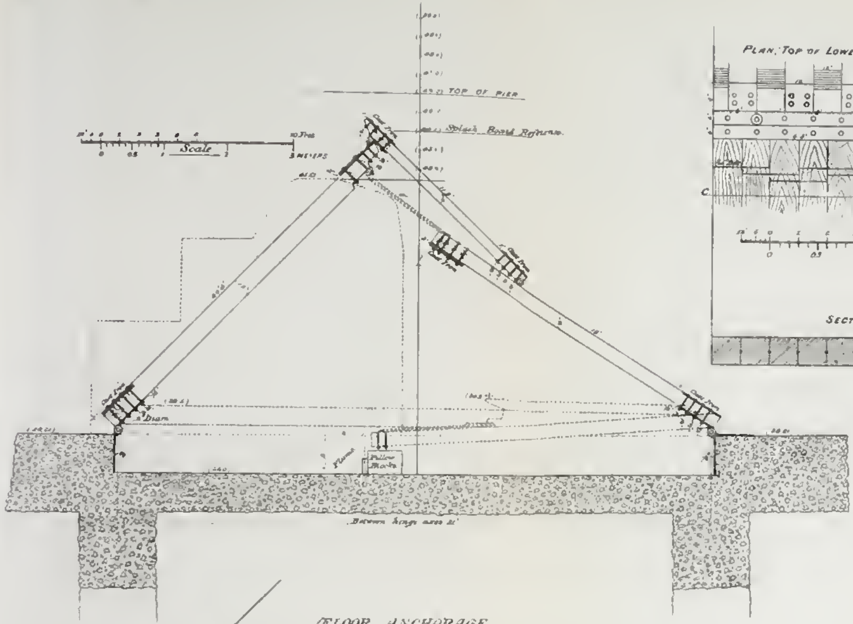
Idler Hinge *Section A.B.*

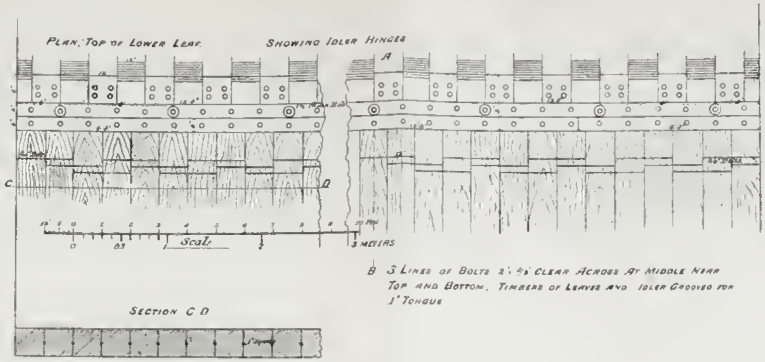


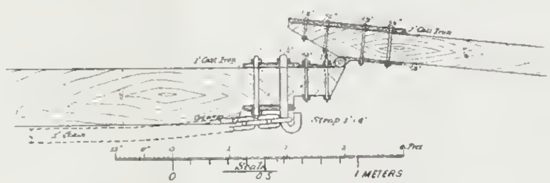
RTRAP WEIRS.

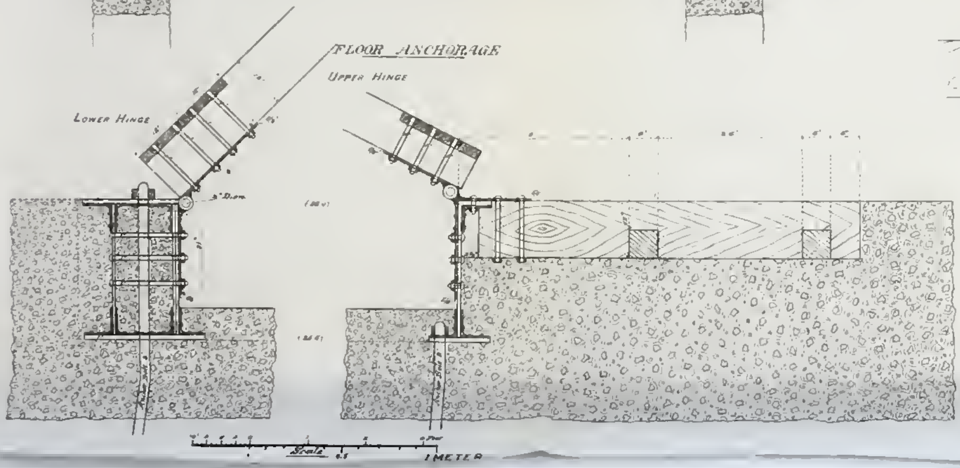
(Jones.)

PLATE III









BEARTRAP WEIRS.

(JONES)

PLATE III.

adjust the effects of undue pressures concentrated at points along the crest, small "bleeder" valves, controlled by the operator observing buoys along the crest, are introduced so as to connect the hydraulic chamber with the lower pool. No attempt is made to stiffen the structure along its length. Let it warp, it will operate just the same, in my judgment. The case is assumed where the river bed is full of boulders down to bedrock, so that piles can not be used in the foundation. The anchorage is effected by a combination of built beams and concrete beams or cores. I would coffer-dam small sections consecutively, such as could be conveniently pumped out.

NOTE.—Since writing the above, the gates at Sandy Lake Dam have failed to operate well, owing to conditions that will not be apparent until after an examination, which will be made as soon as possible.

VI. MODIFIED DRUM WEIR.

By H. M. CHITTENDEN, CAPTAIN, CORPS OF ENGINEERS.

MR. POWELL'S paper is a timely contribution to the literature of movable gates. The subject has of late attracted so much attention that a complete historical review and a summary of existing knowledge pertaining to it, such as are here given, are at this time particularly valuable.

In discussing this paper I shall confine myself mainly to a consideration of the modified drum weir which Mr. Powell has assigned me the credit of proposing.

The principal difficulties which confront the inventor in dealing with any of the "bear-trap" forms of movable gate are:

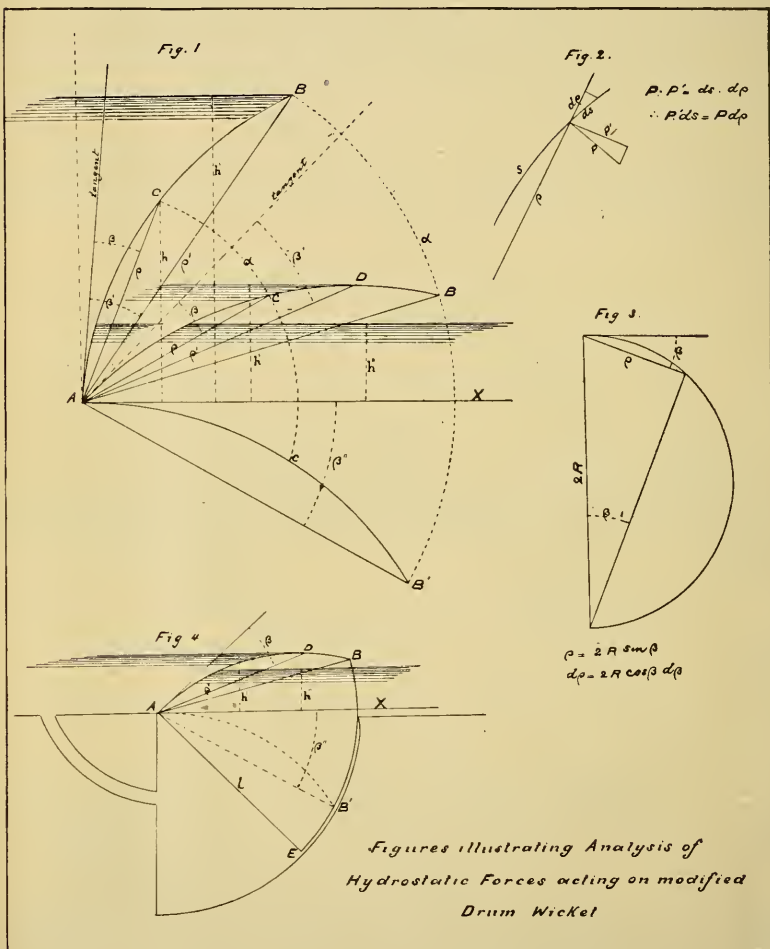
(1) The necessity of having several parallel axes of motion (from two to five) of lengths equal to the width of the sluice which the gate is to close. The mechanical difficulties of constructing and adjusting these hinges so that they may work freely and prevent leakage, are great.

(2) The necessity of having one or more angles either on the upstream or downstream side of the gate in which the lodgment of drift is liable to occur and prevent the complete lowering of the gate. This compels a resort to auxiliary leaves, called idlers, which serve no other purpose than to fend off drift, but which increase the cost, and complicate the operation, of the gate.

(3) The great difficulty of building and operating a long gate in sections, and the consequent necessity of building it all in one piece. The changing positions of the leaves with reference to each other, as the gate

is raised or lowered, make it difficult, if not impossible, to close the ends, so as effectually to separate the chambers, if the gate were built in sections.

(4) Other drawbacks of a less serious nature may be mentioned; such as the sliding surfaces in some forms, which introduce the uncertain element of friction; and the impossibility of intermediate bracing to sup-



Figures illustrating Analysis of Hydrostatic Forces acting on modified Drum Wicket

port pressure surfaces, thus necessitating a heavier and more costly construction.

The proposed modification of the drum weir is free from most of these defects:

(1) It has but one axis of motion and but one hinge.

(2) It has no angles in which drift can lodge, and it therefore requires no idlers.

(3) It can easily be built in sections, since the two pressure surfaces are always in fixed relative positions to each other, and the ends of the gate can therefore be closed.

(4) There are no sliding surfaces, and the two leaves can be made to support each other by proper bracing, thus reducing the weight of the structure to a minimum.

It is urged against this form of gate that the cost of the chamber will be a great drawback. In some sites this would be the case; but in many it would not; as for example where it is proposed to use the gate simply to increase temporarily the height of a fixed weir. The drawings (Figs. 6 and 7) illustrate a case where it is designed to have a movable dam upon a fixed weir, to be kept up in ordinary stages, but to be lowered during flood flow to the crest of the weir. In such a case, if the drum weir were adopted, the chamber would become a part of the fixed weir and would not greatly increase its cost.

It is clear also that the accumulation of silt, sand or gravel in the chamber could be entirely prevented by an arrangement of discharge and inlet pipes, such as is shown in the drawings; for such an accumulation would gravitate to the bottom of the chamber where it could be flushed out without difficulty.

The strong jet which would always issue from whatever space might exist between the cylindrical surface of the gate and the upper edge of the downstream chamber wall would effectually prevent the access of gravel or sticks into such space and the consequent liability to wedging.

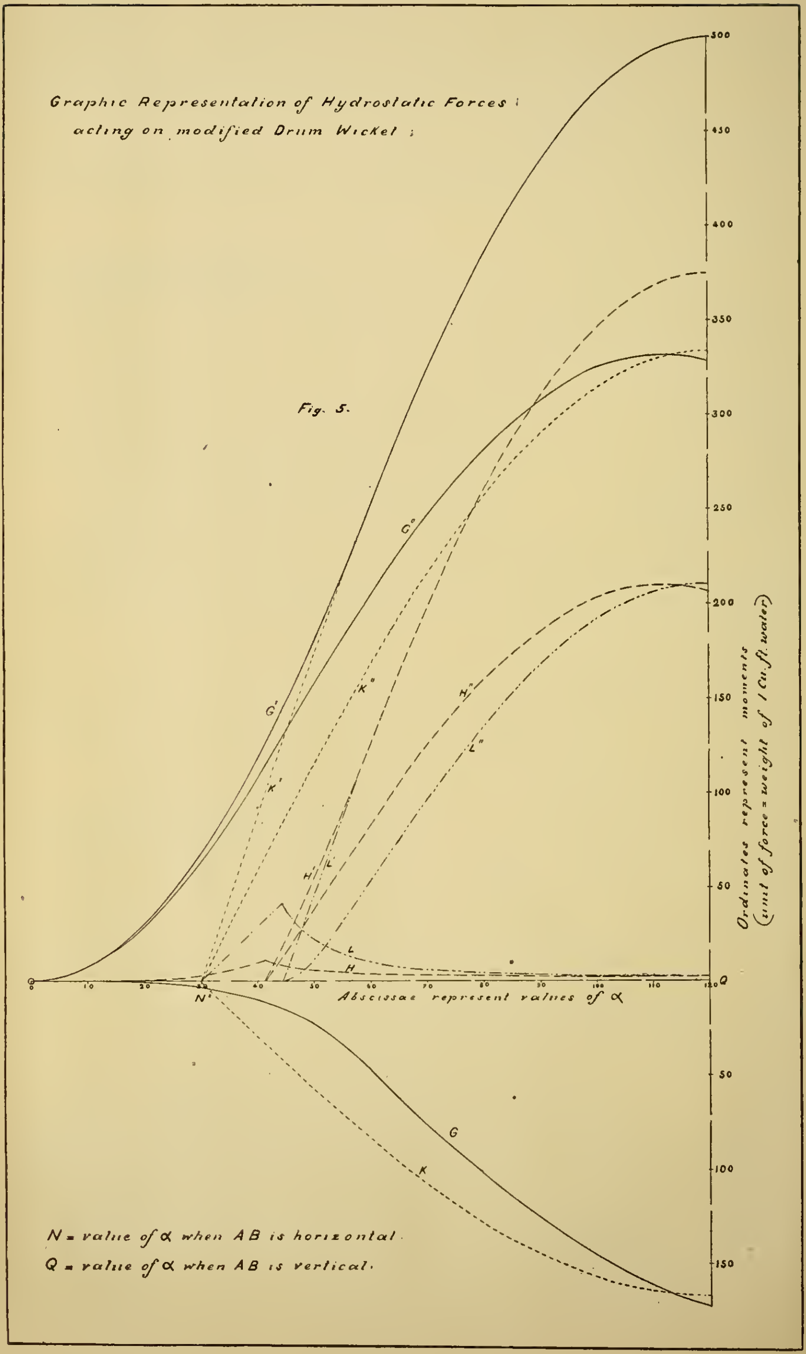
I think there would be no necessity for making the lower leaf longer than the upper, as intimated in Mr. Powell's paper, if the upper leaf were given a moderate curvature, as in the drawing. It is manifest that, for any ordinary stage of backwater, the upper surface of the gate, if of curved form, would emerge at some point between its upper and lower edges, and that the pressure area would then be considerably less for the upper leaf than for the lower. The following analysis shows the effect of such an arrangement. (See Figures 1, 2, 3 and 4).

Let M' = downward moment about point A due to pressure of head h' on cylindrical surface ACB.

" M'' = upward moment on reverse side of same leaf due to backwater h''.

" M''' = upward moment on lower leaf of gate due to difference of head $(h' - h'')$.

" P = pressure per unit of surface at any point, C, due to head $h' - h$.



Graphic Representation of Hydrostatic Forces acting on modified Drum Wicket;
Fig. 5.
500
450
400
350
300
250
200
150
100
50
Q
50
100
150
0
10
20
40
50
60
70
80
90
100
110
120
N'
Abscissae represent values of α
Ordinates represent moments
(unit of force = weight of 1 Cu. ft. water)
G°
G'
K''
K'
H''
L''
H'
L'
L
H
G
K
N = value of α when AB is horizontal.
Q = value of α when AB is vertical.

Let P' = component of P perpendicular to radius vector AC.
" h = vertical distance from horizontal line AX, to any point, C, of curve ACB.
" h' = vertical distance from horizontal AX to surface of water.
" h'' = depth of backwater.
" α = angle of revolution $B'AB$ from origin of motion AB'.
" β = angle between tangent to curve at point A and radius vector from point A to any point, C, of curve. β' is the particular value of β, corresponding to point at which curve ACB meets water surface.
" β'' = $B'AX$ = angle between origin of motion AB', and horizontal line AX.
" ρ = radius vector from point A to any point, C, of curve. ρ' is the particular value of ρ corresponding to point at which curve meets water surface.
" R = radius of curve ACB.
" l = length, AE, of lower leaf of gate (Fig. 4).

In order to arrive at the action of the hydrostatic forces alone, and to determine their maximum effect, let the gate be assumed as without weight or friction, and as rising no faster than the pool behind it. The first two of these conditions can be approximately realized in practice by a proper construction of the gate. The third condition could never be realized, because the great surplus of lifting power would raise the gate to its full height much faster than the pool could follow.

We may now write the following equations:

First.—For the case of a cylindrical surface for the upper leaf.

$$M' = \int_0^s \rho\, P' . ds = \text{(see Fig. 2)} \int_0^{\rho'} \rho . P . d\rho = \int_0^{\rho'} \rho . (h' - h) . d\rho$$

$$h' = \rho' . \sin(\alpha - \beta') \qquad h = \beta . \sin(\alpha - \beta)$$

$$\rho = 2R . \sin\beta \qquad d\rho = 2R . \cos\beta . d\beta$$

substituting and integrating, we have

$$M' = R^3 [4 \sin^3\beta' . \sin(\alpha - \beta') + 2\cos\alpha \sin^4\beta' + 2\sin\alpha \sin\beta' \cos^3\beta' - \sin\alpha \sin\beta' \cos\beta' - \sin\alpha . \beta'] \quad (1)$$

Equation (1) may be used to determine also the upward moments due to backwater h'', by substituting for β' its value, as determined from the following equations:

$$\rho' . \sin(\alpha - \beta') = h'' \qquad \rho' = 2R\sin\beta'$$

For the equation of moments due to pressure on the lower leaf, upon which the upward movement of the gate depends, we have

$$M''' = R . l^2 \sin\beta' \sin(\alpha - \beta') - \tfrac{1}{2} l^2 h'' \quad (2)$$

Second.—For the case of a plane surface for the upper leaf.

$$M_{,} = \frac{\rho'^3 \sin(\alpha - \beta'')}{6} \tag{3}$$

$$M_{,,} = \frac{h''^3}{6 \sin^2(\alpha - \beta'')} \tag{4}$$

$$M_{,,,} = \tfrac{1}{2} \rho' l^2 \sin(\alpha - \beta'') - \tfrac{1}{2} l^2 h'' \tag{5}$$

In these last three equations the origin of motion is taken as AB', the same as in the case of equations (1) and (2), for the sake of algebraic and graphic comparison. In practice β'' would generally be zero and the equations would be correspondingly simplified.

These equations are graphically represented in the curves, shown in Fig. 5, the particular assumptions being $R = 10$ feet, and $\beta'' = 30°$.

EXPLANATION OF CURVES.

First—For the case of no backwater.

G = curve of downward moment due to pressure of upper pool on convex cylindrical surface ACB (Fig. 1).

G' = curve of upward moment due to pressure of upper pool (h') on lower leaf of gate.

G'' = resultant curve obtained by combining G and G'.

K, K' and K'' are corresponding curves in which the upper leaf of the gate is taken as a plane surface.

Second—For the case of an assumed backwater equal to $\frac{1}{4}$ AB (Fig. 1).

G = same as above.

H = curve of upward moment due to pressure of backwater on reverse or concave side of cylindrical surface ACB (Fig. 1).

H' = curve of upward moment due to pressure (h'–h'') on lower leaf of gate.

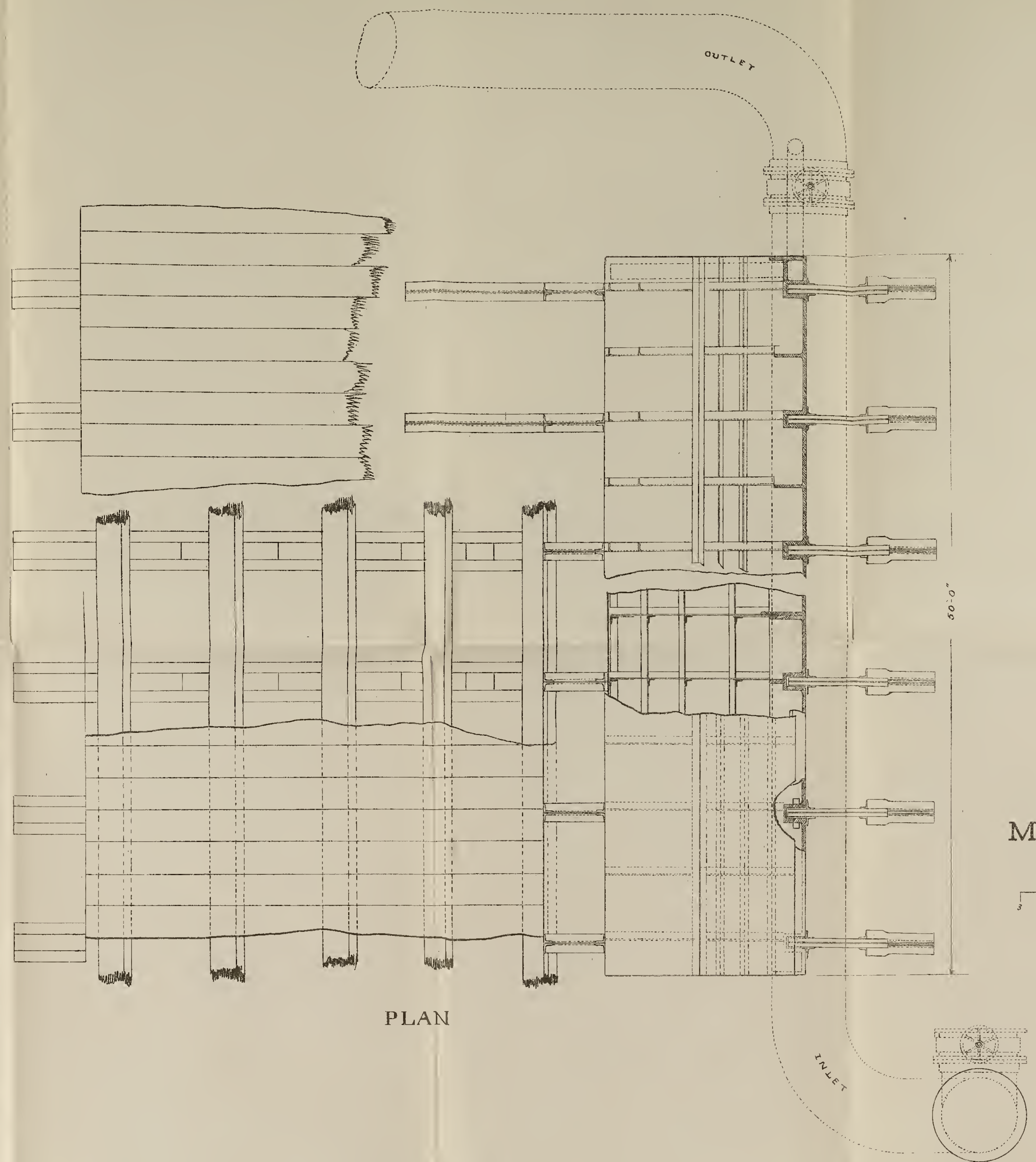
H'' = resultant curve obtained by combining G, H and H'.

K, L, L' and L'' are corresponding curves in which the upper leaf of the gate is a plane surface.

These curves show clearly the considerable gain resulting from the cylindrical form of the upper leaf. With full data for a particular site, the gate could readily be designed so as to give a safe preponderance of upward over downward pressure as it emerges from the pool.

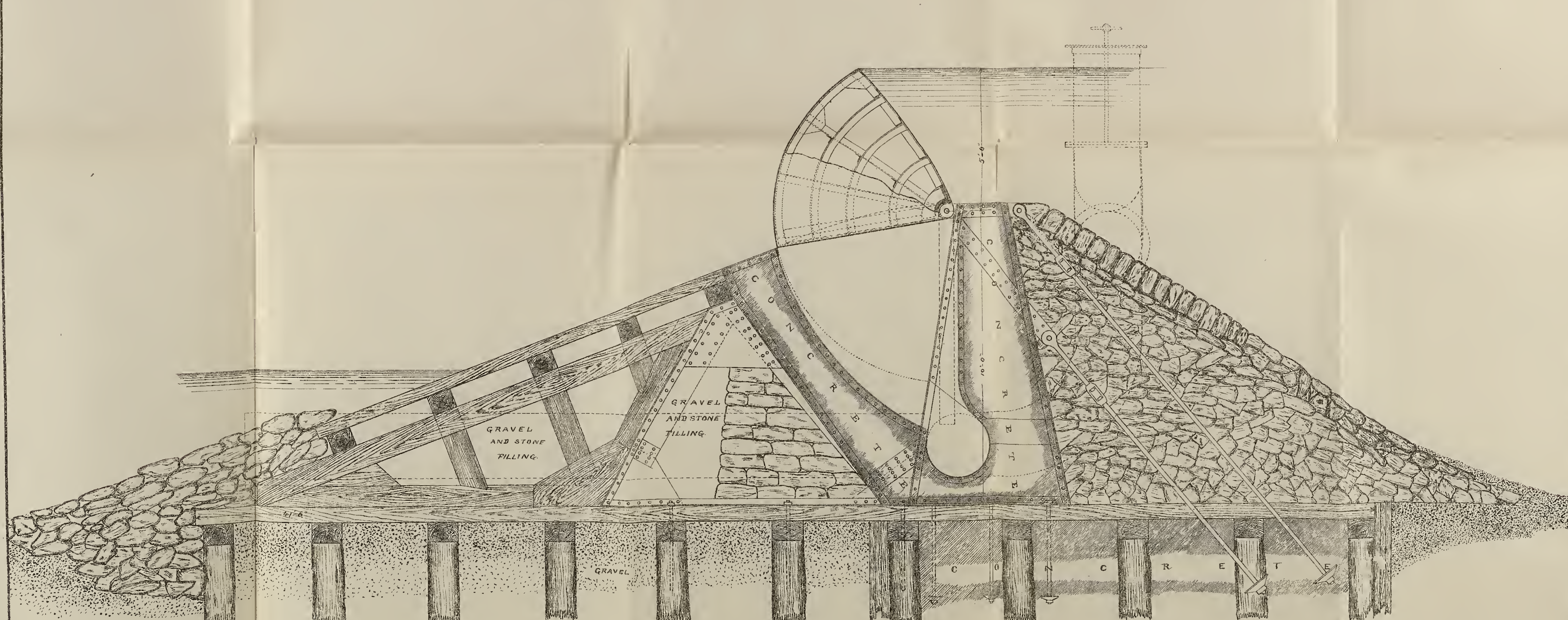
In sites like those shown in the accompanying drawing, where there will always be a considerable initial head whenever it is desired to raise the gate, the lower leaf can be made somewhat shorter than the upper and still provide ample power to operate the gate. The depth of the chamber could, in such cases, be materially diminished.

* See figure, p. 257.



PLAN

THE
MODIFIED DRUM WICKET
SCALE



CROSS SECTION

It should be noted, as an advantageous feature in this form of gate, that the rigidity of construction rendered possible will effectually prevent any tendency to warping or binding such as has been experienced in certain other forms, particularly in the case of the old bear-trap.

The gate requires no chain or other form of stop to arrest motion when it has reached its proper height. The automatic release of water from the chamber accomplishes the same purpose without shock to the structure.

Not the least valuable feature of this form of gate is the fact that it is an enclosed ponton, which can be filled or emptied at the will of the operator on shore. To accomplish this, it needs only a pipe extending the entire length of the dam, with branch pipes, controlled by valves, leading to the interior of each gate, and the whole connected with a pump of suitable capacity on shore. The operation of the gate is thus made independent of the question of initial head, and the gate can be raised or lowered even when the water stands at a level above it.

I take this opportunity of correcting an erroneous impression to which my article in the *Engineering News* of February 7, 1895, seems to have given rise among the advocates of the Lang pattern of movable gate. The term "efficiency," as it appears in the extract quoted by Mr. Powell, p. 22 of this paper, was used solely in a technical sense to indicate "ratio of height to base," as Mr. Powell has elsewhere defined it. It had no reference to the general merits of the gate.

VII. Lifting Dam.

By Amos Stickney, Lieut. Colonel, Corps of Engineers, U. S. A.

The movable dam here described is one designed by the writer for closing the navigable pass at Dam No. 6, Ohio River.

CONSTRUCTION.

The pass* is 600 feet in width, and the dam for closing it is divided into twelve equal sections, operated either together or in divisions of three sections each, and the arrangements for operating will permit, by proper manipulation of valves, the lifting or dropping of any division separately or of all the divisions simultaneously. Each section is about forty-nine feet in length, and the space between two sections is about one foot. Each section, when down, is in a chamber, the upstream and downstream walls of which are of concrete. The walls separating adjacent chambers are of 12-inch white oak timbers. The sections of the dam are constructed of white oak and white pine or fir, strongly bound together and

* See figure, p. 257.

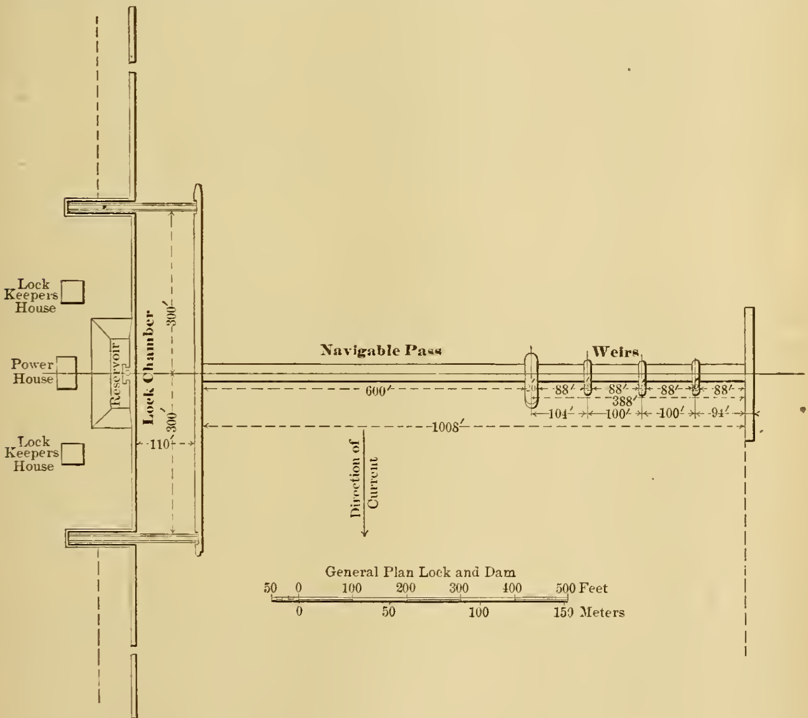
braced, forming stiff cellular structures, so arranged, that whatever position they may occupy, nearly every timber of the structures is constantly in contact with and saturated with water. The purpose of this feature is to prevent or retard decay. A section, in rising or falling, presses against a series of rollers on a shaft along the top of the downstream wall, the upper part of the section revolving around the foot line of the steel props, which are fastened to pins on a line along the top of the section. When the section is up, it rests in a slanting position, with the bottom against the rollers, and the top against the props, and is prevented by stoppers from leaving the chamber. The section is lifted by the pressure of water under the head maintained in a reservoir back of the lock wall; and afterward kept in position by the pressure due to the head of the upper pool, the water in the chamber being connected with the upper pool. The section is dropped by cutting off the connection between the chamber and the upper pool and making connection between the chamber and the lower pool, the section dropping by the preponderance of its weight over that of the displaced water.

In the mass of concrete forming the upstream wall of the chambers is a tunnel, 9 feet in diameter, lined with vitrified brick. This is the filling tunnel, and extends from the river wall of the lock to the pier on the outer side of the pass. Each chamber is supplied with water from the filling tunnel by four iron pipes, 2 feet in diameter. These pipes start from the tunnel above the bottom line so as not to receive any sediment that may settle in the tunnel, and they deliver the water in pits, at the bottom of the chamber under the section of dam. Each pipe is closed by a balanced valve operated by a rod extending to the lock wall, or to the pier. The valves are connected in groups of twelve on one rod, that is the valves for three sections of dam are operated together. Two rods, each operating three sections, are manipulated by a lever on the lock wall, and two rods, each operating three sections, are manipulated by a lever on the pier. The discharge tunnel, with the connecting pipes, in the downstream chamber wall, is similar to the filling tunnel, but placed at a lower level to facilitate the passing of any sediment that may find its way into the pits at the bottom of the chambers. The filling and discharge tunnels have such large cross-sectional area, as compared with the areas of the connecting pipes, that equable pressures will be maintained in all parts of each chamber.

The reduction of pressure in a chamber, due to leakage, when the section is up, is largely prevented by the free supply of water, and the arrangement of packing where the section emerges from the chamber. The packing on the downstream side is a timber, supported on arms which hold it against the face of the dam, while revolving on the roller shaft. The timber has a slight motion on the arms, so that it can be

closely pressed against the dam by the water. The upstream packing is a timber which has a very slight horizontal motion up and down stream, which enables it to follow the movement of the upstream face of the dam.

From an examination of the drawings it will be seen that there is very little opportunity for gravel, or other sediment (except such as is held in suspension in the water) to get into the tunnels or chambers; and if any should get in, it can be easily and effectually removed by sluicing. Any such accumulation in the chambers passes into the discharge tunnel, while that in the tunnels passes into the pier, from which it would be



sluiced out through the sloping conduit leading into the river at the lower end of pier.

The foot of each permanent prop is of a peculiar hook shape, so that it can be lifted off the pin, in case a log or other drift gets under the prop while the dam is dropping. To provide against the contingency of the closing of the water inlets by the matting of small drift on the screens, and to insure against the dropping of the dam, movable props are provided, which are to be placed from a boat, on the upstream side of the dam.

The reservoir, to furnish water under a sufficient head for the initial

lifting of the dam, is constructed back of the land wall of the lock and has sufficient capacity to lift the whole dam to its full height. It is filled by natural flow through a conduit from the lock chamber while the river is at a high stage, but can be filled at any time, or at any stage of the river, by a pump in the pump well. There are two tunnels each 6 feet in diameter, leading from the reservoir under the lock chamber, to the filling and discharge tunnels. These are closed, at the reservoir, by large, horizontal, balanced valves, and each has a connection with the pump well. The pump in the well serves two purposes: first, the filling of the reservoir when necessary; and, second, the emptying of the tunnels when necessary, so that they can be entered from the wells in the lock wall and in the pier. The pump could be run by an ordinary steam engine, but I should prefer an electric engine, connected directly with the pump shaft, the current being furnished by a dynamo in the power house. Submarine cables should pass through the tunnels to furnish light on the pier, and with the necessary connections for attaching lamps in the tunnels.

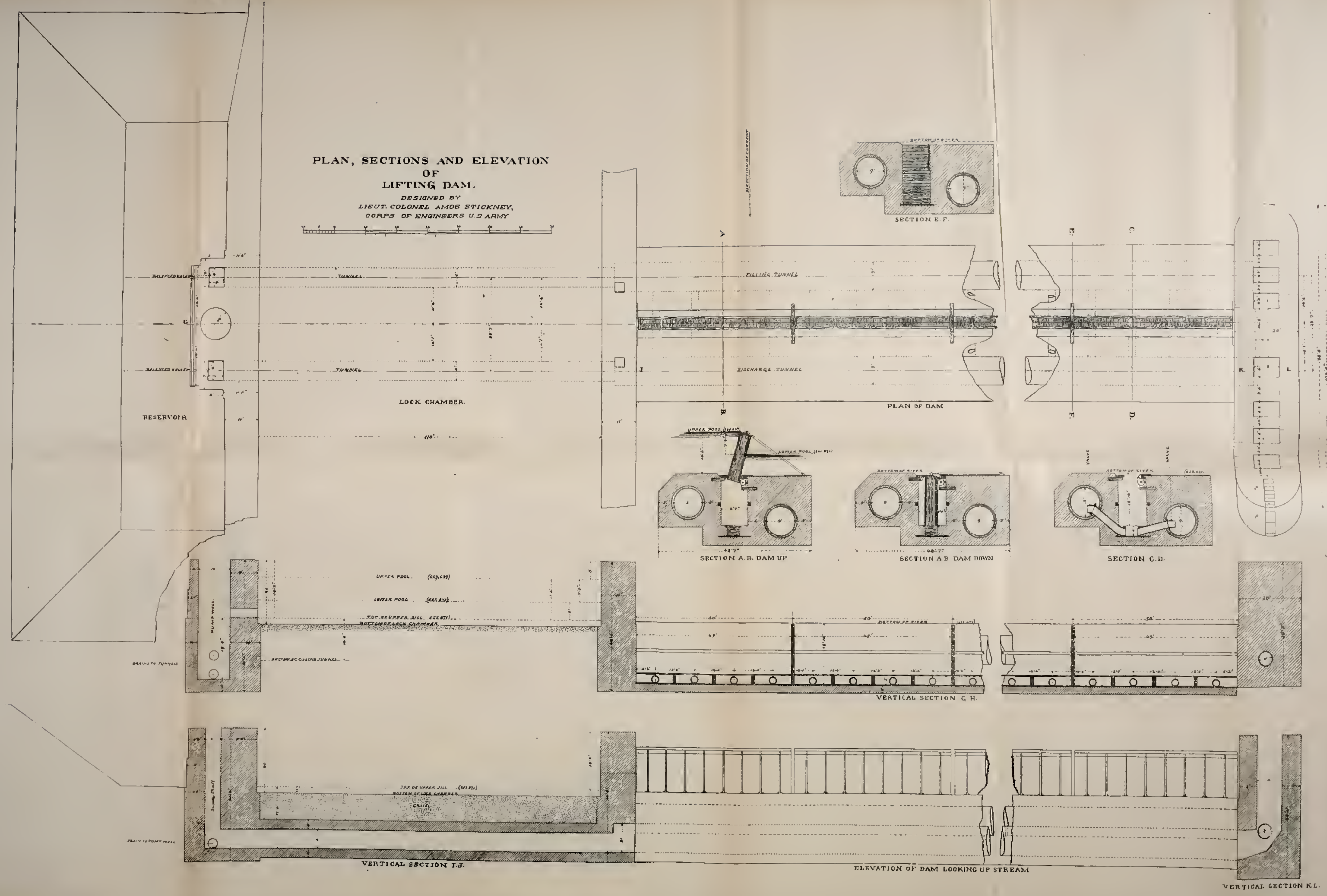
OPERATION.

There are different methods of operating, varying with the order in which the various valves are manipulated; and by any of the methods the entire dam could be lifted at once, or it could be lifted by divisions of three sections each.

The following is one method of operating:

The dam is supposed to be down, lock gates open, and the river flowing freely. The reservoir is supposed to be full, having been filled by flow from the river at a higher stage, or pumped full. All inlet valves for the dam are closed, all outlet valves open, preventing any upward pressure in the chambers.

The first operation would be the closing of the lower gate of the lock chamber. Then, to lift the entire dam at once, close the discharge valves in the pier; open the valves in the pipes leading from the filling tunnel; open the reservoir valves for one or both tunnels. The water from the reservoir will then flow into the chambers from one or both tunnels, lifting the dam. By the time the level on the dam reaches that of the river surface, sufficient head will have been accumulated for raising the bear traps that close the weirs. The flow of the river being then completely stopped, the upper pool will rapidly rise and develop a pressure on the upstream side of the dam in excess of the back pressure from the lower pool. As the resultant of all pressures on any section of dam outside of its chamber is in a line passing downstream and above the line of the feet of the props, there will be a tendency to revolve around the feet of the props, and this tendency develops a lifting force in addi-


PLAN, SECTIONS AND ELEVATION
OF
LIFTING DAM.
DESIGNED BY
LIEUT. COLONEL AMOS STICKNEY,
CORPS OF ENGINEERS U.S. ARMY
RESERVOIR
LOCK CHAMBER.
TUNNEL
FILLING TUNNEL
DISCHARGE TUNNEL
PLAN OF DAM
SECTION E.F.
SECTION A.B. DAM UP
SECTION A.B. DAM DOWN
SECTION C.D.
VERTICAL SECTION G.H.
VERTICAL SECTION I.J.
ELEVATION OF DAM LOOKING UP STREAM
VERTICAL SECTION K.L.

tion to the pressure in the chamber. When the upper pool has risen sufficiently, the inlet valves in the pier should be opened, thus enlarging the supply of water, under pool head, to the chambers. When the dam is lifted to its full height, the movable upstream props and joint covers may be placed at leisure. The dropping of the dam would be accomplished by a reversal of the operations for lifting. By a study of the valves it will readily be seen how the dam could be lifted or dropped in various ways, and in its entirety, or by divisions of three sections. Less than twelve inches of head will move the dam, and this might be reduced by giving the structures a little more buoyancy, and the necessary head could be obtained, in a stream of considerable slope, without a reservoir, by laying an inlet pipe some distance upstream.

It is probable that if it should be found desirable, the dam could be dropped part way and held, by regulating the pressure in the chambers through partial opening of discharge valves. All valves in the dam are balanced, and are operated by turning hand levers 180°. One man on the lock wall, and one on the pier, could in a very few minutes manipulate all valves necessary for lifting or dropping the dam.

In all cases where more than one valve is operated by one motion, the valve stems are connected with the throwing rod by spiral springs, so that if clogging prevents one valve from completely closing, it will not prevent the others from closing. This device has operated very successfully at the Davis Island Lock.

ADVANTAGES.

The advantages of this type of movable dam are many, and of a nature to justify a considerable increase in cost of construction over that of other types that have not the same advantages.

First, the rapidity and ease with which the dam may be lifted or dropped, thus damming or throwing open a river in a few minutes, is an advantage of incalculable benefit in a river subject to sudden rises. It does away with the requirement of a nice judgment as to the exact time of lifting or dropping the dam, and the possible serious consequences arising from inability to quickly change the river from one state to another; and it does away with the necessity of any elaborate or costly arrangement for notifying the operatives as to the condition of the river above the dam.

The second advantage is in the comparatively small amount of leakage through the dam. In many of the types of movable dams the leakage is so great as to render it exceedingly difficult to maintain a full pool in the dry season, when the flow of the river is very small.

The third advantage is that only a small force is required for operating.

The fourth advantage is in the safety of the men operating the dam, in any kind of weather, day or night.

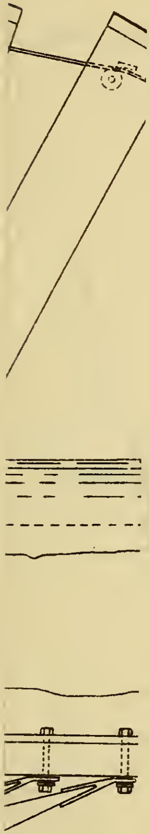
Another advantage, not to be overlooked, is the ability to maneuver the dam under any conditions of the river, even with the water flowing over the dam, so that the safety of the structure itself is not dependent upon the watchfulness and forewarning of the operatives.

VIII. A Design for a Movable Dam.

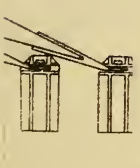
By B. F. Thomas, U. S. Asst. Engineer, Mem. Am. Soc. C. E.

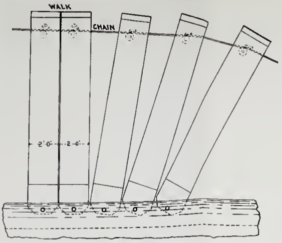
In raising a Chanoine wicket dam, as now constructed, it is first necessary to raise a series of trestles for a service bridge from which to erect the wickets; then a winch is moved along this bridge, and each wicket is raised separately. At best the process is slow and laborious. To lower the wickets, the winch is again moved along the bridge and the wickets are first pulled upstream a few inches, against all the head of water, and then released. After they are all lowered, the trestles are let down one by one. The wickets and trestles have long chains attached to them for maneuvering. In a needle dam the trestles are raised precisely as in a wicket dam. They are connected by bars below the floor level. The needles are then placed from the top of the bridge by plunging them into the water, the foot striking a sill and the head resting against the connecting bar. To lower the needles these connecting bars are released at one end, permitting the needles to fall. A rope is passed through their heads and attached to the bridge so that they cannot float off. After the needles have all been released the trestles are lowered, the ropes holding the needles being tied to a long line fastened to the lock-wall. The Poirée trestle was first used as a support for the heads of needles; next, for a service bridge from which to raise and lower wickets, and finally for supporting gates set directly against the upstream face of the trestle. It is used for all these purposes at present. It is now proposed to make the trestle itself do all the work, without the addition of needles, wickets or gates.

It is evident that in order to accomplish this the trestles must touch each other when standing, otherwise the spaces between them must be closed with an independent construction, a needle. In streams of large discharge this would not be objectionable, but in those of small discharge it might be difficult to keep the pools up during the dry season. Still, even if the trestles were spaced one foot apart and if a joint cover or needle were used when necessary on the whole or a part of the dam, a tighter dam would be secured than those at present in use, either of needles or wickets. But if the trestles are so spaced as to touch each other when standing, how are they to be lowered? In the

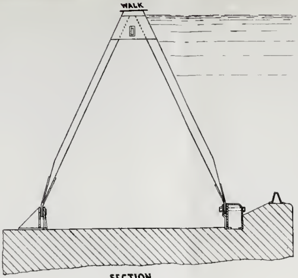


OWN.

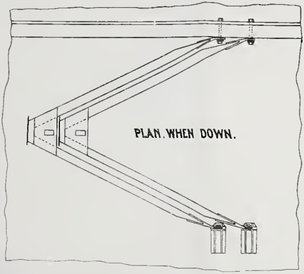




ELEVATION.



SECTION.



PLAN. WHEN DOWN.

DESIGN FOR A MOVABLE DAM,

BY B. F. THOMAS,
U. S. ASST. ENG'R

SCALE
0 1 2 3 4 5 6 FEET
0 0.5 1 2 METER

first place it is necessary to suppress all diagonal bracing, then suppress the axle and substitute pins for journals. The next thing is to give the posts a decided inclination, the upper one downstream and the lower one upstream. The trestle then has the shape of the letter A. If horizontal braces are retained, they must be placed upon one side only—viz: that which will lie next to the floor when down; but they may project so as to support a neighboring trestle, when up.

Having secured a trestle of this form and design, it will be seen that one will lie flat within another, provided the legs are not too thick, and provided, further, that a sufficient inclination has been given the posts. The boxes which connect the trestle legs to the floor must also be designed in such shape that the trestles will not strike them when down. Having designed a trestle which will hold the water back and will lie on the floor out of harm's way when not needed, it remains only to devise a means for raising and lowering it under all conditions. This is accomplished by means of a chain connecting with each trestle and terminating at a crab on the lock wall. The chain is held on a chain-wheel in the head of each trestle by a guide directly over the wheel. The turning of the wheel may be stopped or started by a ratchet and pawl. The length of chain between two adjoining trestles is greater than their distance between centers, so that several trestles are raised or lowered at once like the sticks of a fan. After the first trestle is up, the hauling in of the spare length of chain between it and the next is effected by releasing the ratchet in the first and allowing the chain to pass on, as the crab is turned. As each trestle comes upright and strikes its neighbor, it automatically releases the pawl from the ratchet. The chain is necessarily much longer than the dam. The length of chain left between successive trestles will, of course, depend on the power of the maneuvering winch—*i. e.*, upon the number of trestles it is desired to have *en route* at one time. In lowering the trestles the pawl is thrown into the ratchet as the chain is paid out by reversing the winch, each trestle being thus made fast to the chain before it starts down. The ratchet can not be released from the pawl till the trestle is raised again.

Details as to pool regulation, walkway above pool level, etc., need not be described here. This style of trestle is applicable to any of the places now occupied by the Poirée trestle, and has the advantage of requiring a much less depth of sill for its protection.

HIGHWAY BRIDGES.

By Carl Gayler, Member of the Engineers' Club of St. Louis.

[Read before the Club, April 15, 1896.*]

In preparing a paper on this subject I have endeavored to bring out a few points which might explain the very limited success of former agitations for an improvement in the building of highway bridges, and to discuss at some length the present practice, not of the highway-bridge companies, but of the structural engineers who have made highway bridges a specialty.

It is now four or five years since the movement for a reform in the highway-bridge business was at its height. The technical papers of that time are full of editorials and letters on this question; several prominent engineers and professors of civil engineering devoted their time and influence to it; the Engineers' Clubs of Chicago, St. Louis and Kansas City had committees appointed and reports adopted, and in several States drafts of proposed acts of legislature were prepared and came very near being introduced. And with this the movement came to an end, after having accomplished very little; and highway bridges are being built about in the same manner as before.

As there is no doubt that an improvement in the building of highway bridges is desirable, this failure is remarkable and seems to indicate that the fault lay with the proposed remedies. There is a good deal of force in the objections first raised by Mr. Horton, of the Western Society of Engineers, against the principal proposed remedy, *i.e.*, legislative enactments. It seems unjust to transfer the control over highway bridges from the cities and counties to the State, as the former originate the work, pay for it and have to maintain it.

A perusal of what has been written and proposed at that time leaves, furthermore, the impression that the movement was not sufficiently comprehensive; it might be characterized as efforts to secure legislation providing for expert examinations of the strain sheets of proposed new highway bridges and examinations of such old ones, the safety of which had given rise to doubts. But how about the preliminary work, deciding on the length of span, clear waterway, foundations, character of masonry and—assuming the superstructure to be built according to the proposed State official's directions—the maintenance of the bridge? Surely, every one of these points requires the services of the bridge engineer. Counties will have to follow the example of our large cities, and employ capable engineers for their highway bridges.

* Manuscript received June 20, 1896.—*Secretary, Ass'n of Eng. Socs.*

Wherever in cities and counties public works are in the hands of engineers, State supervision is unwarranted; where county commissioners rely on their own wisdom a limited supervision, as proposed at the time of the late reform movements, is insufficient.

Whenever one of the periodical unusually heavy rains flood a section of the country, we read about a number of bridges having been washed out; such occurrences are generally regarded by the profession with considerable equanimity, as if it were in the natural order of things that abutments and piers are underwashed, or superstructures carried away by floods which surely should never have reached them, whilst the occasional breaking down of a highway bridge is carefully noted, and still gives rise to spasmodic appeals for legislation. Why this important question of sub-foundations was never included in the efforts of the reformers, why it is likewise hardly ever mentioned in books and treatises on highway bridges, has always been a mystery to the writer. Some remarks on this subject may not be out of place.

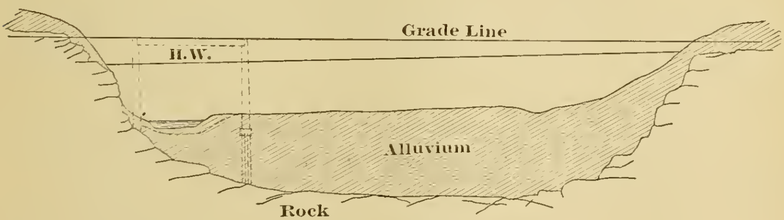


Fig. 1

The cross-section of a valley, as shown in Fig. 1, through which a road is supposed to be built, requiring the crossing of a creek or stream, is typical of the cases with which I had experience; it is probably also typical of the greater number of cases in this part of the country. It is a broad valley, with steep banks and an alluvial bottom. The rock is near the surface on both bluffs, the alluvium extends down to considerable depth, and the water-course is near one of the two banks. A glance will show this valley to have been in former ages the bed of a great river, which, probably assisted by the action of ice, hollowed out its immense bed in the rocks. Subsequent sinking of the land or diminishing of the volume of water, or both causes combined, raised the level of the bed of the river, and the valley filled up with boulders, gravel or sand, or with clay, from the ice period, and, closer to the present watercourse, with more recent deposits. To form an intelligent judgment of the contemplated foundations, an insight into the history of the valley in by-gone ages, assisted by some general knowledge of geology, is necessary. Borings or test-pits will complete what is necessary to plan the foundations and estimate their cost. The grading of the highway and

the building of the substructure reduces the free waterway in time of floods, a deepening of the water channel, often, also, a shifting of the water-course, caused by the dying out of the vegetation, takes place, and these changes in the water-course are most important in designing the foundations and, unless taken well into consideration, will cause the destruction of the bridge in short time.

That this preliminary work, as well as the building of the abutments and piers, should be in the hands of the bridge engineer, will be readily conceded.

The superstructure of the American highway bridge has been developed by the highway-bridge companies, and it has been truly stated in regard to the best examples among them, that "greater strength and safety are obtained from a given amount of materials than with the methods of construction which prevail abroad." During late years, some of our leading structural engineers have given their attention to this subject, and have published books and specifications on highway bridges. A subdivision of the latter into three classes, according to their proximity to cities, assuming different live loads for each of them, is now the accepted rule. Being more familiar with Class I (or A), *i.e.*, bridges in cities, I will confine part of the following remarks to this class.

It is generally agreed to assume for the live load, beside a concentrated load by which the dimensions of the flooring, stringers, floor-beams and hangers are obtained, a uniform load per square foot, covering the whole and portions of the bridge, ranging from 100 pounds for short spans to 50 pounds for longer spans. It is worth while to consider what this assumed uniform live load really means.

In the case of railroad bridges the live load is simply the weight of the trains, and the unit strains in the truss members have been selected of such magnitude as to give a structure of reasonable rigidity. For the principal tensile members, 10,000 or 12,000 pounds are customary, and for the compression members a reduction is made in the units according to the laws of the strength of columns. These unit strains are far lower than the elastic limit of the material would seem to warrant: they bear no relation to the breaking strength, and the so-called factor of safety may as well be abandoned as an antiquated expression without meaning; they have been evolved from the behavior of bridges under their daily duties. As Prof. J. P. Snow, in a recent discussion on the strength of iron railroad bridges, puts it: "What is the basis of the present units? Examinations of bridges in service. In order that a bridge may be satisfactory it must remain rigid under trains and deflect but very little. These conditions can only be obtained by using low units." Now, with highway bridges the case has just been reversed. We start out with unit strains borrowed from the railroad bridge practice

(increasing them, however, about 25 per cent., for some reason not easily explained) and then choose the live load with the view of obtaining a satisfactory structure. It is well to keep this in mind; attempts to explain the customary live loads for highway bridges in any other way are misleading, if not dangerous.

Since the substitution of steel for iron, some engineers specify for highway bridges of the former material an increase in the unit strains of 20 per cent. Granted that the ultimate strength of steel is 20 per cent. greater than that of iron, and the elastic limit even more, this increase in the units is, for the reasons stated above, not justified, as the modulus of elasticity of steel exceeds that of iron but little. By far the greater number of highway bridges, with their plank floors, are light structures; there is little mass in the metal to overcome the effects of the jolting of wagons over the rough planks, or of the trotting of horses; the vibrations are accumulative and we should be slow in adopting an increase of units. Increasing, or doubling the units for the dead load should only be resorted to for very long spans, or for bridges with extremely heavy floors. I may be permitted to state here that my experience in this city with four steel spans of 120, 135, 150 and 220 feet length, designed for the live load of Cooper's A, but for unit strains of iron railroad bridges, no increase in them being made for units under dead load, has been such that I have never felt guilty of a waste of material in designing them, and that they have convinced me that the usual specifications for this class are too light.

Specifications and books on highway bridges and standard details for the same, as published in the latest works, have left the impression on the writer that this subject has not been treated with the conscientious care bestowed on other structural work. Whether the temporary and unsatisfactory character of most of the floors, or the fact that bridges built in accordance with these books and specifications are still far above the general practice all over the country, or the certainty that the bridges when completed will in nine cases out of ten be neglected and go to wreck and ruin anyway, can explain their neglect, I am unable to say.

The consideration of rigidity, which have led to the selection of these live loads, should be the guide in regard to lateral connections and the results of our experience with railroad bridges should with equal care be applied to the highway bridge. In all through spans rigid connections of floorbeams with posts and bottom chords should be insisted upon, not that perfectly safe hangers could not be designed—the latter having even a slight advantage in applying the load centrally to the posts—but the gain in lateral stiffness is too great to be thrown away. It is impossible to prevent altogether a distortion of the structure in a storm or under a

load applied close to one of the two trusses; but with deep floorbeams well riveted to the posts and top lateral struts firmly attached to top and bottom of the top chord, as sketched in Fig. 2, considerable resistance is gained, with details as shown in Fig. 3, next to none.

There is one feature in through bridges to which never yet full justice has been done; it is the top lateral bracing. The universal custom is to design it to withstand the wind pressure (generally assumed to be 150 pounds per linear foot of top chord). Now there is not the least doubt that it should be made strong enough to resist the wind forces, but there is just as little doubt that if a bridge were thoroughly protected against wind, the top lateral system would still have to prevent the top chord from buckling; more than that, I am convinced that no storm ever strains

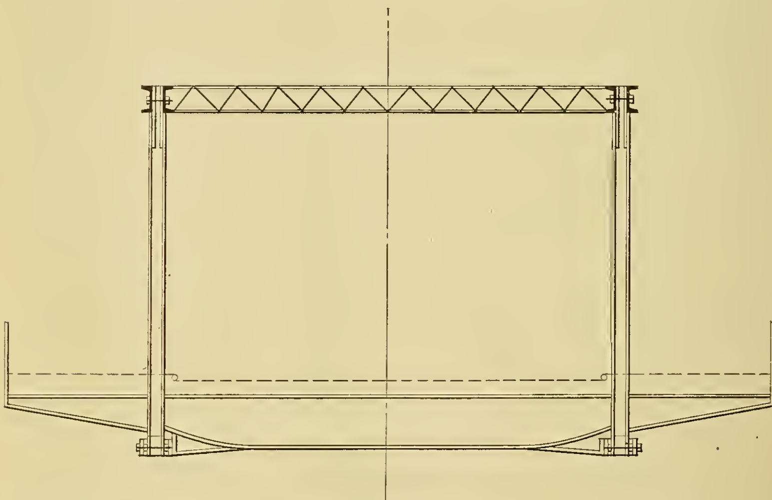


Fig. 2

it as the top chords do under their full duty. Anyone standing on a railroad bridge with a train moving over it can satisfy himself on this point. It seems to be against sound judgment to design the top lateral system of a through span on the same supposition as the bottom lateral system of a deck span. This is one of the many instances where the strain sheet alone is no sufficient guide. The engineer has to use his experience and judgment to design a lateral system of sufficient rigidity; no theory in the world will enlighten him on the amount of lateral pressure exerted by an exceedingly long column. Mr. Waddell, in his book on highway bridges, states in this respect, without, however, entering into the question, that the top lateral rods in highway bridges up to 200 or 230 feet length, if proportioned for wind pressure alone, are too light.

The above remark that the strain sheet does not cover every case

applies with equal force to the specifications. It has been too much the custom to let highway bridges under a set of specifications, limiting the work of the consulting engineer—in case an engineer is consulted at all—to checking the figures and sizes. This custom, more than anything else, has made a highway bridge superstructure a mere merchandise. Nothing is, for instance, easier than to specify "a substantial railing" for a bridge, yet nothing is more indefinite and more difficult to enforce. Specifications are necessary, but we need even more the judgment of the engineer; we need more designing and less standards.

I have no intention of entering into the question of the relative superiority of pin-connected or riveted highway bridges, but there is one type in which the latter are infinitely superior to the former, *i. e.*,

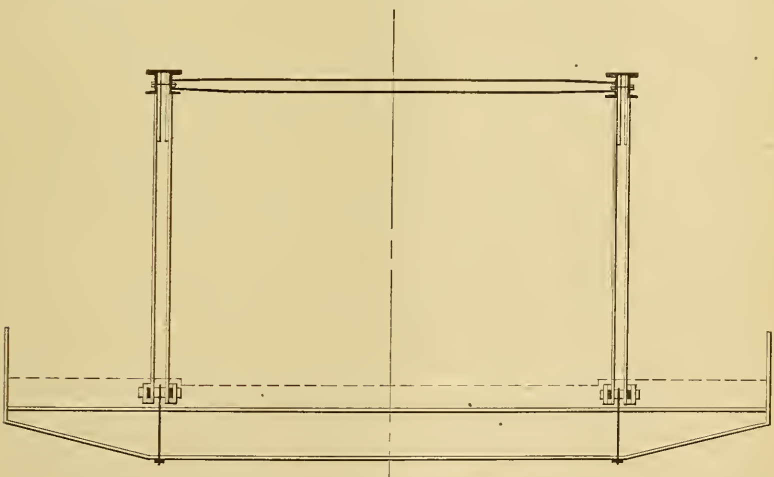


Fig. 3

the short span pony truss. If designed with pin connections the lack of lateral stiffness is exceedingly difficult to overcome; with a riveted design we easily obtain a most excellent structure.

The subject of floor systems could easily be made to take up your whole time for an evening, and will not be discussed beyond calling attention to the new departure which has been occasioned through the advent of the electric motor car. That it will be of the very greatest moment is apparent; we have in this city motor cars, weighing, when crowded with people, 24 tons, carried on two trucks 25 feet apart; we have others of 18 tons weight when full of people, the trucks being spaced 14 feet between centers. In the first motor cars the load on each truck was distributed equally on both axles; to gain in tractive force the pin was

then shifted so that about 75 per cent. of the load came on one axle, and in the latest cars (on Jefferson and Grand Aves.) the whole weight is carried on the driving axles. The first motors of 15 horse-power have been succeeded by 25 and 50 horse-power motors; girder rails 6, 8 and 10 inches deep have taken the place of the flat rail of the old street cars. It is not more than six years since electricity began to be generally applied to the city and suburban transportation, and it is not likely that the motor car, especially on long suburban lines with heavy grades, has attained its greatest weight.

Assuming now a bridge to be completed, the work of the engineer is still not over. In a few years the floor will need looking after, parts of the ironwork and railing require attention and the paint will begin to show those ugly spots which indicate that the work of deterioration has begun. This question of painting is the bane of the structural engineer's life, the one point where his knowledge is at fault and where his only recourse is to get the rust scratched off and new paint smeared over it. It does not matter very much what kind of paint he uses, iron oxide, lead paint or asphalt, so long as he tries to get a good brand and makes the most of his limited knowledge of the oil and the pigment; in all probability he will use them all in turns and in turns be disappointed. Protection of metal against atmospheric influences by paint applied cold is temporary.

Rusting is most to be feared and most difficult to prevent on surfaces which are close together without being in close contact throughout, as at pin joints between the heads of eyebars and the adjacent portions of the posts and chords. Taking apart old pin-connected trusses we find the greatest corrosion on the sides of eyebar heads. It should not seem to be impossible to remedy this by filling these spaces with an impervious material; to my knowledge this has been successfully done on the lower chords of the heavy Pauli trusses of the Monongahela bridge at Pittsburgh. In riveted work there is no excuse for such dangerous spaces between different members, but we still find too often, through faulty riveting or where rivets have been spaced too far apart, that we can insert the blade of a knife between angles and plates, especially at the stiffness of large web sheets.

Such weak points will probably never be quite overcome; the wonderful example of the Eads bridge, where the sides of the eyebar heads of the main arches and the adjacent sides of the joint blocks were planed and all the exposed joints of the covers of the tubes were carefully caulked, will never be imitated, but the designer of structural work should keep this question always in mind.

The action of corrosion in wrought-iron work in cases where painting is utterly unavailing—and it has been my luck to have a number of

such cases under my charge—is peculiar. A hard shell of corroded iron of pretty uniform thickness forms over the whole exposed surface; this shell scales off to make room for the formation of another shell, and this process goes on until nothing is left to scale off. It might not unreasonably be supposed that this process of scaling off in layers is peculiar to wrought iron as a material rolled and welded in layers, and that steel, being a homogeneous, crystalline metal, would better resist the attack of rust. Should this prove to be true, what a splendid bargain did we make in exchanging iron for steel!

Bradley & Poates, Engr's, N.Y.

Association of Engineering Societies.

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PROCEEDINGS.

Civil Engineers' Society of St. Paul.

St. Paul, Minn., January 6, 1896.—Regular meeting of the Civil Engineers' Society, held at 8.15 p.m. Thirteen members and one visitor in attendance. President Stevens in the chair. Amended minutes of previous meeting read and approved. The government of the Society was requested to report a proposed amendment to the constitution to cover settlements with delinquent members. The annual reports were read and placed on file. The Librarian was authorized to arrange for a year's subscription to the following periodicals: *Engineering Magazine, Engineering News, Engineering Record, Engineering, Trans. Am. Soc. M. E., Trans. Am. Inst. E. E.* The Librarian was also requested to procure the current *Proceedings of the Engineers' Club of Philadelphia* by exchange, if possible. Mr. W. L. Darling was elected a member. The present incumbents of all offices were re-elected. Upon motion, a committee of three was appointed to consider and report upon so much of the Parker Retrenchment Committee's Report as related to the City Engineer's department. C. F. Loweth, A. O. Powell and J. D. Estabrook constitute the said committee. Mr. A. H. Hogeland led the discussion of the evening with a description of the effect of earth slides on the Great Northern Railway bridges which cross the Red River of the North and its tributaries. Mr. C. F. Loweth explained and illustrated the circumstances of the movement of Pier No. 1 of the Northern Pacific Bridge at Bismarck. Immediately before adjournment the President appointed the following gentlemen to serve on the Examining Board for the ensuing year: A. O. Powell, J. H. Armstrong and Oliver Crosby. Mr. Loweth was appointed to audit the accounts of the year just closed.

C. L. Annan, *Secretary.*

January 20, 1896.—The Civil Engineers' Society of St. Paul held its annual dinner, followed by a special meeting, at the Windsor Hotel, to receive the report of the special committee appointed to investigate the justice and accuracy of the recommendations of the retrenchment committee upon the city engineering department. The report was a strong and exhaustive one, completely refuting the insinuations of extravagance made by the retrenchment committee against the City Engineer's department. It was unanimously adopted.

The committee appointed by the Civil Engineers' Society to make the investi-

gation reported informally that it had spent several days in making the investigation. It had gone through the books of the engineer's office thoroughly, and grouped the facts. It had ransacked the office from top to bottom, and was convinced that its conclusions were correct. How much work had been done by the committee might be gathered from the fact that one of the sessions lasted twelve consecutive hours, and that ten hours alone was spent in "boiling down" the first draft of the report, so as to make it concise and pointed. The consequence was that the committee had a multitude of facts and figures in abeyance, all tending to prove and support its conclusions.

The personnel of the committee carried great weight with the members of the society, as all the members were men of exceptional experience and conservatism. The members were C. F. Loweth, chairman; A. O. Powell and John D. Estabrook.

The apparent disposition to abandon the manual training school was discussed after the committee's report was disposed of. President H. E. Stevens and Messrs. Estabrook, Woodman, Loweth and Crosby all expressed it as the result of their individual observations that the school was a most important adjunct to the city's educational system. In conclusion, a resolution offered by Mr. Crosby, protesting against the disposition to curtail the usefulness of the school, was adopted.

C. L. Annan, *Secretary.*

Technical Society of the Pacific Coast.

Regular Meeting, held January 3, 1896.—Called to order at 8.30 p.m., by President Dickie.

Minutes of the last regular meeting read and approved. The Nominating Committee selected at the last regular meeting submitted the following report through its chairman:

To the President and Members of the Technical Society of the Pacific Coast: Your Committee on Nominations for the offices to be filled at the Annual Meeting desire to report the following ticket:

President—Geo. W. Dickie.
Vice-President—W. G. Curtis.
Secretary—Otto von Geldern.
Treasurer—E. T. Schild.
Director—L. Falkenau.
" W. F. C. Hasson.
" Randell Hunt.
" J. D. Isaacs.
" J. C. Sala.

Very respectfully (for the Committee),
(Signed) C. E. Grunsky, *Acting Chairman.*

Mr. John D. Isaacs stated to the Society that he had been prevented from completing a paper for this evening, and that he would submit such paper at the next meeting of the Society.

It was ordered, upon motion, that Mr. Isaacs' paper be read after the regular business of the Annual Meeting to be held January 17th.

The members present discussed the patent laws of the United States informally, after which the meeting adjourned.

Otto von Geldern, *Secretary.*

ANNUAL MEETING held January 17, 1896. Called to order by President Dickie.

Messrs. C. E. Grunsky and Hubert Vischer, having been appointed tellers to count the ballots for the officers of the Society for the ensuing year, they declared the following ticket elected in regular form:

President—Geo. W. Dickie.

Vice-President—G. W. Curtis.

Secretary—Otto von Geldern.

Treasurer—E. T. Schild.

Directors—Louis Falkenau, W. F. C. Hasson, Randell Hunt, J. D. Isaacs, Jos. C. Sala.

The Secretary read his report for the year 1895, which was ordered received and adopted as read.

The reading of Mr. Isaacs' paper was laid over until the next regular meeting of February.

The matter of appointing a Standing Committee to investigate, collect and formulate data that bear upon the character and specific qualities of our Pacific Coast timbers, and to show by experiment and design the best use of modern practice in the manifold ways in which this material is applied, was considered, and upon motion a committee was appointed by the Chair, consisting of Professors Frank Soulé, Albert T. Smith, and Messrs. John D. Isaacs, Randell Hunt and George W. Percy, who are to constitute a Standing Committee on Pacific Coast Timbers.

After discussing the prospects for the coming year and the usefulness of the Society to the industrial pursuits of California, the meeting adjourned.

Attest: OTTO VON GELDERN, *Secretary.*

ABSTRACT OF THE ANNUAL REPORT OF THE SECRETARY FOR THE YEAR 1895.

THE present total membership is 167, as follows:

Honorary members	3
Members	151
Juniors	6
Associates	7
Total	167

Of these 89 are resident and 78 non-resident members.

89 reside in San Francisco and vicinity; 55 in other parts of California.

Professionally divided there are: 3 architects, 66 civil engineers, 4 electrical engineers, 29 mechanical engineers, 18 mining engineers, 12 surveyors.

During the year 1895, the Society added to its membership 18 members and 2 juniors.

MEMBERSHIP OF THE SOCIETY IN JANUARY, 1895.

Members and associates	205
Admitted in 1895	20
Total on membership list in 1895	225

Loss During 1895.

Deaths	5
Resignations	8
Suspensions	45
Total	58
Present membership	167
Decrease in 1895	38
Number of regular meetings held during the last year	10
Social meetings (Banquet)	1

Subjects Read and Discussed.

1. Comparison between Steam and Gasoline Traction Engines. *Ernest F. Rossow.*
2. Transmission of Intelligence by Electricity. *Frank P. Medina.*
3. Stopping a Troublesome Slide at Summit Tunnel. *John D. Isaacs.*
4. Reconstruction of the Car Ferry Transfer Aprons at Port Costa and Benicia. *John B. Leonard.*
5. Engineers: Consulting, Inspecting and Contracting; their Relationship to each other and to the Public. *Geo. W. Dickie.*
6. Some Experiments on Water Ram in Pipes. *Chas. D. Marx.*
7. The Construction of a Large Wrought-Iron Wheel. *Edward S. Cobb.*
8. Pacific Coast Timber; its Tests and Treatment. *Frank Soulé.*
9. The Cyclotomic Method of Transit Observations. *Otto von Geldern.*
10. Released Ashlar: a Problem in Building Construction and Ornamentation. *John Cotter Pelton.*
11. Recent Improvements in Coal Handling Machinery. *John D. Isaacs.*

Of these, numbers 3 and 4 have been published, while the others will appear in print from time to time.

On March 1, 1895, the Technical Society became a member of the Association of Engineering Societies, and its papers were published in the Journal of the Association.

In addition, the Society issued a separate publication of its professional papers, in publishing the reprints of the Association under the title of "Transactions of the Technical Society of the Pacific Coast," January to July, 1895.

This bulletin contains 94 pages with the following

Contents:

Portland Cement Concrete at Fort Point. *George H. Mendell.*
The Industrial Problem of the Pacific Coast.
I. Address of the Retiring President, Mr. *C. E. Grunsky.*
II. Inaugural Address of the President, Mr. *Geo. W. Dickie.*
The Relation of Railroad Transportation to Production in California. *R. L. Dunn.*
Should our Patent Laws be Abolished or Modified? *John Richards.*
Pressure and Impulse in Motive Engines—A Look into the Future. *John Richards.*
Timber-Preserving Methods and Appliances. *W. G. Curtis.*

Representatives on the Board of Managers are:

W. F. C. Hasson, Electrical Engineer.
Hubert Vischer, Civil Engineer.

The past year of our Society has been a more prosperous one than could have been expected under the existing business depression. While we record a loss of

thirty-eight names over and above the admissions during the year, it must be remembered that many of these members had been in arrears for dues for some time, and were merely allowed to remain on the list, until it was ordered by the Executive Committee that all members, in arrears for over one year, should be placed on a suspension list, and should not be entitled to the publications. Such a course became absolutely necessary in order to avoid incurring an expense for which there was not an immediate return.

For this reason it became necessary to place forty-five members on the Suspension List, and this is the cause for what appears to be a great loss in the active membership of the Society.

Any one of these members may, by paying the arrearage to the date of his suspension, be reinstated to his standing in the Society.

Engineers' Club of St. Louis.

428TH MEETING, JANUARY 8, 1896.—President Ockerson called the Club to order at 8.10 P.M., at 1600 Lucas Place. Thirty members and one visitor present.

The Executive Committee reported the doings of its 204th and 205th meetings, approving the applications for membership of W. S. Brown, S. F. Crecelius and O. E. Overpeck. They were balloted for and elected.

The Executive Committee recommended that instead of the usual roster there be issued this year an annual bulletin, to include the list of members, officers and committees, constitution, by-laws, programme, etc., which have heretofore appeared in the annual publication; and, in addition, the reports of officers and committees read at the annual meeting, and also the addresses delivered at the annual dinner. A limited number of selected advertisements to be included, with a view of reducing its net cost. On motion, ordered that this matter be left to the discretion of the Executive Committee.

The Secretary reported that a contract had been entered into with the Missouri Historical Society for renewal of the Club's lease for quarters in their building for two years.

The Secretary announced the resignations of J. I. Ayer, J. G. Kelley, W. S. Love and C. B. White, to date December 31, 1895.

Nominations being called for to fill the vacancy in the office of director, Mr. William Bouton was nominated. On motion, ordered that the Secretary cast the ballot of the Club for Mr. Bouton. This was done, and Mr. Bouton declared duly elected director.

The Secretary read letters of regret at their inability to attend our annual dinner from the Presidents of the Minneapolis, St. Paul, San Francisco, Kansas City and Helena Engineers' Clubs.

Mr. Geo. B. Leighton then read a paper on "Some Notes on English Railway Practices." It was illustrated by numerous maps, drawings and pamphlets. The speaker described at some length the essential features of English railways, calling special attention to those points in which their practice differed radically from ours.

The speaker also gave an account of the International Railway Congress held in London in June, 1895, which he had attended, together with some remarks on the social features connected with the meeting.

The discussion was participated in by Messrs. Moore, Crosby, Johnson, Hermann, Kinealy, Russell, Maltby and Pitzman. Adjourned.

WILLIAM H. BRYAN, *Secretary.*

429TH MEETING, JANUARY 22, 1896.—President Ockerson called the Club to order at 8.30 P.M., at 1600 Lucas Place. Twenty-seven members and five visitors present.

The minutes of the 428th meeting were read and approved. The Executive Committee reported the doings of its 206th meeting. Applications for membership were announced from W. G. Comber, U. S. Assistant Engineer; Horace Dunaway, surveyor with Mississippi River Commission; and J. L. Van Ornum, instructor civil engineering, Washington University.

Mr. E. J. Spencer then addressed the Club on "Underground Electrical Service," giving the results of the wide study and varied experience which the speaker had had in work of this character, in different parts of the country. He reviewed the historical features of the subject, explaining the work done both at home and abroad, the difficulties which had been met with and how they had been overcome.

It is not generally known that the first experiments with the Morse telegraph were made with underground circuits; these gave so much trouble that the entire matter was on the point of being dropped, when an assistant suggested trying overhead wires. This being done, the experiment was immediately successful. The speaker explained the work which had been done in New York, Philadelphia, Boston, Chicago, and elsewhere, and regretted the fact that St. Louis was moving so slowly. He stated that there was no city east of St. Louis of 150,000 inhabitants or more, which did not have its wires underground in the business districts. He showed a number of samples of cables of different types and for a wide variety of purposes.

Messrs. Moore, Bryan and Flad participated in the discussion. Adjourned.

WILLIAM H. BRYAN, *Secretary.*

The Civil Engineers' Club of Cleveland.

CLEVELAND, O., JANUARY, 1896 —Meeting of the Civil Engineers' Club of Cleveland, Tuesday evening, January 14th.

Present, 57 members and visitors. In the absence of the regular officers, Mr. Searles was called to the chair. The minutes of the last meetings were read and approved. Messrs. Varney and Cooke were appointed tellers to canvass the ballots for the election of Mr. J. S. Covert.

The Executive Committee reported, in regard to the special Library Fund, that $210 for the year had been subscribed and $175 collected. That the special contract had been arranged with Case Library whereby they were to appropriate as much more as we raise every year to the purchase of technical works, and that a special alcove was now devoted to our use on the second floor of the Case Library building.

All members are requested to send to the Librarian the titles of any books they consider suitable for the Library.

That a Committee, consisting of General Barnett, L. E. Holden and C. H. Strong, had been appointed to draft resolutions upon the death of our brother member, General Leggett. (Owing to the absence of General Barnett from the city, they did not report this evening.)

From the Committee on Coinage, etc., House of Representatives, United

States of America, a bill to fix the standard of weights and measures by the adoption of the metric system. Referred to the Executive Board.

Communication from the Architectural Club, offering the privilege of an evening to be known as the Civil Engineers' Club evening, when the Clubs should visit the exhibition together. Referred to the Executive Board.

The following were appointed a committee to nominate officers for the coming year: S. H. Searles, A. Swasey, A. Mordecai, W. R. Warner, Walter Miller.

The paper of the evening, "Quadruple Expansion Engines for Lake Service," was then read by Mr. Walter Miller. Discussion upon the paper was taken part in by Messrs. Oldham, Newman, Swasey and others. The whole was very interesting.

Mr. W. W. Sly then gave an illustrated talk on "Tunneling Machinery."

After the meeting the Club adjourned to the restaurant and partook of a light lunch. F. A. Coburn, *Secretary.*

Montana Society of Civil Engineers.

The ninth annual meeting was held in the Society's office at the Board of Trade rooms in Helena, Montana, January 11, 1896. The meeting was called to order at 11.15 A.M.

The members present were: Messrs. Keerl, Smith, Monroe, Bickel, Dewar, McArthur, Ryon, Thorpe, Mumbrue, Cumming, Page, Wickes, Hovey, McRae, Haven and Parker. There were present also about twenty invited guests.

The minutes of the last meeting were read and approved.

The tellers reported that John Randolph Parks and John Cameron Patterson were elected members of the Society.

The following officers were declared unanimously elected for the ensuing year:

President, John Herron; Vice-President, James M. Page; Second Vice-President, A. E. Cumming; Secretary and Librarian, Forrest J. Smith; Treasurer, A. S. Hovey; Trustee for three years, W. A. Haven; Member of the Board of Managers of the Association of Engineering Societies, James S. Keerl.

Applications for membership of Frederick Charles Scheuchs, A. J. Seligman and Frank Joseph Steever, were read. The Secretary was instructed to refer Mr. Steever's application back to him to be made out in more detailed form and handed to the Trustees for approval.

The newly elected First Vice-President took the chair.

The Secretary and Treasurer submitted reports which were referred to the Board of Trustees.

The Committee on Arrangements reported that passes had been secured for the members on the different railroads leading into Helena.

Mr. Keerl, the retiring President, as Chairman of the Committee, extended an invitation to the members of the Society and their guests to a reception at his residence, from eight o'clock until midnight. The invitation was accepted by the Society.

A vote of thanks was extended to the agents and managers of all the railroads who kindly sent passes to members of the Society not residing in Helena.

Two letters of withdrawal were read, one from Albert B. Knight, of Butte, and one from A. F. Whitcomb, of Vermont. The withdrawals were accepted by the Society as provided for by the Statutes, and Mr. Whitcomb was placed on the list of the Associate Members of the Society.

AFTERNOON SESSION.

The retiring President, Mr. James S. Keerl, referred to the progress of the Society during the past year. There had been added to the rolls of the Society twelve new members, and there were added three more during the day. During the year the Society had listened to the reading and discussion of various papers on a variety of appropriate topics, among the best of which was one by an ex-President of the Society, E. H. Beckler, describing a narrow gauge railroad, built for W. A. Clark, in Arizona, for the transportation of copper ores; another by Maurice S Parker, a member of the Society, of Great Falls, on the cost of water and steam power in Montana.

Mr. Keerl then read his address on Relative Standing of Engineering among the Professions.

The subject for discussion before the meeting was a paper formerly read by J. H. Farmer, on "Water Power by Electrical Transmission," in relation to the mills and manufactories of Helena, a synopsis of which is given below:

Amount of dry Montana fir and pine wood consumed in generating one horse-power per hour	4.4 pounds.
Cost of wood per cord, averaging 2,910 pounds	$3.50
Cost of one horse-power, for 365 days of twenty-four hours	70.50
" " " " " " " " " " " " using Montana coal.	71.56

Estimated cost of one horse-power, generated by water power, and transmitted by electricity to central power-station in Helena:

Cost of dam, power-house, etc., to develop 90.10 horse power on wheel shaft	$6.10 per horse-power,
Transmission to Helena (12 miles)	10.68 " " "
Total fixed charges for 365 days of twenty-four hours, for power delivered in Helena	16.78 " " "
Saving over best steam tests	53.72 " " "

The dam is to be of masonry, of the following dimensions:

Height	30 feet.
Length	740 "
Length of weir section	400 "
Crest width	10 "
Bottom width, at 68 feet depth	50 "

Minimum flow of Missouri River, at Stubbs' Ferry, 200,000 cubic feet per minute.

Mr. Herron presented results of tests of wood and coal at Marysville, Montana, with Corliss Compound Condensing Engine with 14″ and 24″ x 42″ cylinders developing 143 horse-power.

Original cost of plant	$92.00 per horse power
Interest, repairs, etc.	10.00 " " "
Cost of one horse-power for 365 days of twenty-four hours, using Montana coal, at $3.60 per ton, 2,000 pounds	3.69.
Cost of wood, per cord of 2,800 pounds	3.69.
Cost of one horse-power for 365 days of twenty-four hours, using dry pine wood	118.55.

Mr. Parker.—My investigation of the cost of steam power under various conditions and comparative cost of water power, fully bear out the statements made by Mr. Farmer in this connection.

The cost of steam power can readily be determined when cost of fuel is known. That of water power must be ascertained by careful investigation. I find the average cost per horse-power for developing water power, including electrical transmission up to the distance of thirty miles, to be about $2.00 per net per horse-power. In the development of a water power for long-distance transmission, the cost of electrical development remains constant so to speak ; that is, there is little opportunity for reduction in the cost of this plant. Therefore, in the construction of a water-power plant for the generation and transmission of electricity, the saving in first cost must necessarily be in the development of the water power. It, therefore, behooves the engineer, designing such a plant, to look well into the subject before recommending the plan for adoption, and submitting then only such a plan as is consistent with economic principles and with results to be obtained. In regard to the efficiency of water wheels. Under the most favorable conditions, the best wheels give 85 per cent., as stated by Mr. Farmer, but in practice I find 75 per cent. efficiency to be given for wheels under general conditions. Another loss of 25 per cent. in electrical transmission for distances up to thirty miles can be safely counted upon. I allow, in my own calculations, a loss of 50 per cent. always between the actual gross horse-power of a stream and the effectual transmitted power.

Mr. R. E. Chandler.—I should like to draw attention to the very high evaporation power which the wood, used in tests given by Mr. Farmer, must possess.

According to this table, 4.4 pounds of wood were burned per horse-power per hour. It has been usual to figure one pound of wood as equivalent to .4 of a pound of coal. On this basis, the engine would be showing an efficiency equivalent to generating a horse-power on 1.76 pounds of coal per hour.

Mr. Parker.—The cost of the development of water power at Great Falls, with a dam of an average height of 15 feet, and crest nearly 800 feet long, was $175,000. I am sure, from my own investigation of the site under discussion, that a combination crib-dam, 30 feet high, could be built for $100,000, and that the entire plant for the delivery of electricity to the amount of 3,445 horse power at a central power-house in Helena, could be constructed within the cost of a dam and other works at Stubbs' Ferry, as estimated by Mr. Farmer. I know that the cost of water power, in some of the principal States using it, is about $13.00 per horse-power. The cost for wheels for power-house is about $50.00 for the amount they use. The actual charge for power against each branch of industry is charged with the amount of power it consumes at the rate of cost. Two or three instances I have in mind—the actual cost of power is from $13.00 to $25.00 ; at Black Eagle Falls, it is $13.00 ; at Great Falls, $16.00, and at Spokane Falls, as high as $25.00.

Mr. Bickel.—Have you formed any idea what the horse-power would cost from the river here?

Mr. Parker.—Only approximately. It would cost $10.00.

Mr. Bickel.—What they could not sell here, they could sell at the river?

Mr. Parker.—Yes. There is one thing in the building of works at the river ; that is, the entire amount of power that can be generated there. The base of the dam would be built for the idea of carrying the dam 30 feet high. The dam could be built 15 feet high and a crest that can be carried up in it with a power that would warrant the money. If the dam, at 30 feet high, would have cost $100,000, then at 20 feet, it would have cost about $75,000. That leaves $25,000 there, and the

necessary wheels would only have to be set in the power-house, and be built for the size that is needed for the full amount of power as fast as it is needed for the consumers. It need be only large enough to answer the call for it. There are quite a number of items in Mr. Farmer's estimate that are very low in my opinion. For instance, the cost of masonry. There are 1,922 cubic yards in the facing, at $10.00, which would cost $13.00 per yard. 420 cubic yards, at $14.00, would probably cost $22.00. Some of the other items for coffer-dams and pumping are perhaps large enough; but the estimate for rubble masonry, as it is here mentioned, is evidently given for dry-land work rather than for water work. It sometimes costs 20 per cent. more for water work than when constructed on dry land; but that is mere guess-work.

Mr. Ryon.—There is another point that should not be overlooked. The past year, I have been keeping a record of some of the rivers in Montana, which are near Bozeman, among them the Jefferson, Madison and Gallatin rivers, the principal water-supply of the proposed plant under discussion. I notice that in the flow of these rivers about the irrigation season, there is a decided drop in each of them. Every year we are taking out water from them, and may it not be true that in ten years from now it will be very low, owing to the fact that irrigators are taking the water out?

Mr. Parker.—In that connection, I would like to state that I have a daily record kept at the Missouri River at Great Falls. The overflow of the dam at the Falls constitutes a good weir, in fact, almost a perfect weir. I find that the flow of the river has increased every year since 1890. It may drop back in the next five years, but what water is taken from the river above seems to have very little effect upon it at that point. The seasons of 1889–90 were the driest seasons that have been known for some years; so I do not think that the amount of water taken for irrigation cuts very much figure in the general flow at present.

The President.—I think your position, Mr. Parker, bears out the experience that has been had before. Water taken out of the river for that purpose, usually returns to it, lower down.

It was then ordered that a record of the papers and their discussions, and of the meeting, be printed and placed before the Board of Trustees.

The Secretary then read the following resolutions upon the resignation of Prof. J. B. Johnson, as Chairman of the Board of Managers of the Association of Engineering Societies. The resolutions were adopted, and it was ordered that a copy of them be sent to Prof. Johnson.

Resolved, That the Montana Society of Civil Engineers learns with sincere regret of the resignation of Prof. J. B. Johnson as Chairman of the Board of Managers of the Association of Engineering Societies, and appreciates the untiring zeal and deep interest which have characterized the discharge of his duties while occupying that position. It recognizes the healthy growth of the Association during his incumbency of the office, the labor of love displayed through his conscientious and successful efforts to maintain in a fitting manner the Index Department of the Journal, and his invaluable services, rendered fully and timely, to the advancement of the interests of the Association.

Resolved, By the Montana Society of Civil Engineers, that a copy of this preamble and resolution be enrolled upon our minutes and published in the Journal of the Association of Engineering Societies, and that a copy be forwarded at once to Prof. J. B. Johnson, wishing him a long life in which to continue his self-appointed task of earnest endeavors toward advancing the interest and the progress of the engineering profession.

The meeting then adjourned. F. J. Smith, *Secretary*.

Boston Society of Civil Engineers.

JANUARY 22, 1896.—A regular meeting of the Boston Society of Civil Engineers was held at its rooms, 36 Bromfield Street, Boston, at 7.40 P.M. President Albert F. Noyes in the chair. 142 members and visitors present.

The record of the last meeting was read and approved.

Messrs. Ernest W. Bailey, Wallace C. Brackett, Andrew D. Fuller and Theodore Horton were elected members, and Mr. Herbert L. Grew, an associate of the Society.

The Secretary read a memoir of Phinehas Ball, a member of the Society, prepared by Messrs. Charles A. Allen and Lucian A. Taylor.

On motion of Mr. A. H. French, the President was requested to appoint a committee of three to retire and report to the meeting the names of five members to serve as a committee to nominate officers for the ensuing year. The President appointed as this committee Messrs. French, FitzGerald and McClintock. Later in the meeting this committeee reported the names of Messrs. J. R. Freeman, A. E. Burton, Allen Hazen, G. A. Kimball and C. H. Swan, and upon motion the members named were elected a committee to nominate officers for the ensuing year.

The President stated that the Trustees of the Boston Public Library desired the Society to become responsible for the use and safe return of books loaned to those of its members who are not residents of Boston and to whom cards had been given in consequence of their membership. On motion, the Secretary was authorized to sign an agreement satisfactory to the Trustees.

The Secretary read a letter from Mr. Frank L. Locke, resigning the office of Librarian of the Society, and on motion the resignation was accepted. It was further voted that the committee to nominate officers chosen at this meeting be requested to report at the next meeting a nomination for librarian to fill the vacancy.

On motion of Mr. Wood the thanks of the Society were voted to President Eliot, of Harvard University, for courtesies shown this afternoon on the occasion of the visit to Harvard College.

The following resolution, adopted at the last meeting, was ratified by a vote of 37 in favor and 2 against:

Resolved, That the Boston Society of Civil Engineers earnestly deprecate the use of any of the wire and sheet metal, or other trade gauges now in vogue, and strongly urge the use of a *decimal system* for all such measurements.

On motion of Mr. Whitney, it was voted to hold the annual dinner at the usual time in March. It was also voted that Mr. Henry Manley be a committee to make the necessary arrangements, and that the sum of $50 be appropriated for the incidental expenses of the dinner.

Mr. Howard A. Carson then gave an informal talk, in which he described some of the interesting engineering works seen by him in his tour in Europe last spring. The talk was illustrated by a large number of lantern slides.

Adjourned.

S. E. TINKHAM, *Secretary.*

Phinehas Ball.—A Memoir.

By Charles A. Allen and Lucian A. Taylor, Committee of the Boston Society of Civil Engineers.

[Read January 22, 1896.]

Phinehas Ball, eldest son of Manasseh Sawyer and Clarissa (Andrews) Ball, was born in Boylston, Mass., January 18, 1824.

He came of Puritan stock, being descended on his mother's side from Simon and Anne Bradstreet. His father was the youngest son of Elijah Ball, a soldier of the Revolution, who was in General Putnam's retreat on Long Island and attained in 1779 the rank of first lieutenant.

Mr. Phinehas Ball began life with a frail body and his youth was a continued struggle with ill health. The seasons of close application devoted to study and teaching were followed by severe illnesses that ate up his scanty earnings. His early education was limited in the extreme, and such was his poverty that he was at times compelled to settle for his tuition by payments in charcoal and other produce.

In the winter of 1841, he taught school in Southborough; the following winter in Lancaster, and then in Marlborough.

In the fall of 1846 he began studying draughting in Worcester, but was soon prostrated with typhoid fever and unable to do any work until the following April, when he was associated with a Mr. Kirby in Worcester. In June he was employed to survey the Worcester Aqueduct, and was thus enabled to free himself from debt.

His own early struggles made him quick to sympathize with others in like difficulty, and he never failed to help them to the utmost of his ability.

In April, 1849, he became associated with Elbridge Boyden, under the firm name of Boyden & Ball, Architects and Engineers, and the partnership lasted until 1860. He planned the first sewer in Worcester, and his field books, covering a period of twenty-five years, show how closely he was identified with the growth of that city.

While engaged in general work for the city of Worcester he was concerned in the construction of the Taunton Hospital for the Insane, and the Fitchburg Jail. He became a member of the Mechanics' Association in 1853, and served as clerk from 1857 to 1865, being also treasurer for seven years of that time, and afterwards director, vice-president and president for short terms. For seventeen years he was one of the directors of the Mechanics' Savings Bank. In 1862–63 he served the city in the Common Council; in 1865 he was mayor; from 1863 to 1867 water commissioner, and from 1867 to 1872 city engineer.

With the Yankee instinct for the better or quicker method, Mr. Ball patented various devices used in connection with water works. After working for some years on a water meter, he found that Mr. Beniah Fitts had developed a like device, and the two entered into partnership, patented a meter, and in November, 1869, formed the Union Meter Company, of which Mr. Ball was made president. In 1872 he was appointed engineer in the abatement of the Miller's River nuisance.

In 1873–75 he built the Springfield Water Works, and during the same time made plans or gave advice for water works at Nashua, N. H., Amherst, Leominster,

Marlborough, Lawrence, Westborough, Fitchburg, Portland, New Haven and New Britain, and for sewers for Keene, Fall River and New Britain.

In 1876 Mr. Ball received a grievous blow in the breaking of the dam at Lynde Brook Reservoir. It was his first considerable work, and one in which he took just pride, and the disaster cut deep into his sensitive soul. He took refuge in no extenuating circumstance, but worked steadier and found relief in such work. That year he reconstructed a broken dam at Clinton.

In 1879 he began the Brockton Water Works, and continued in the service of that city for a number of years, planning a system of sewers. He also planned sewerage systems for Amherst, Westborough and the Concord and Sherborn prisons and water works for Claremont, N. H., Gloucester, Mass., and additional works for Lynn, Mass., and New Haven, Conn.

In 1887 he began work on the drainage of the Mystic Valley, but the malarial air of the Saugus marsh aggravated his old troubles. He was forced to resign his position the next year, and was not able again to undertake any work of importance. But he was never idle. When forced to remain indoors, experimental chemistry was his resource, and in this study he obtained some results of practical value.

He was much interested in the formation of the Worcester County Society of Engineers, and was its president while health permitted.

In 1894 he enjoyed better health than for a number of years, but in November a little overwork and a chill brought his life rapidly to a close, and he died on the 19th of December.

On December 21, 1848, Mr. Ball married Sarah Augusta, daughter of Captain William Holyoke, of Marlborough, and two children were born to them, Allard Holyoke, who died in 1857, and Helen Augusta, still living. Mrs. Ball died in 1864, and on November 29, 1865, Mr. Ball married Mary Jane, daughter of Benjamin B. Otis, of Lancaster. Mr. Ball joined the Boston Society of Civil Engineers, October 19, 1887.

Bradley & Poates, Engr's, N.Y.

Association of Engineering Societies.

Vol. XVI. **FEBRUARY, 1896.** No. 2.

PROCEEDINGS.

Association of Engineers of Virginia.

Annual Meeting, Roanoke, Va., January 25, 1896.—The annual meeting of the Association was called to order January 25, 1896, by the President, Mr. J. C. Rawn, who submitted the following report from the Board of Directors:

I beg to present herewith a report of the operations of this Association for the year 1895, together with such suggestions as have appeared pertinent to me.

The bad financial conditions which obtained during 1893 and 1894 had so seriously affected all interests, but most particularly such as engineers were dependent upon for a livelihood, that at the close of 1894 a large number of our member-were without engagements and consequently without the financial support necessary to maintain themselves. As a result of this condition, many of our members found it impracticable to meet their obligations to this Association, and either their resignations were accepted or they were dropped from membership for delinquency. A number of our members, but particularly those residing outside of Roanoke, believed that their membership in this Association did not afford them a sufficient return in engineering literature or information. Your Board of Directors recognized the virtue of this contention, and realizing that our revenues were not sufficient to meet the expenses attendant on the publication of our papers, were considering the best means to allay any dissatisfaction and to solidify and strengthen what was remaining of the Association, the membership having decreased nearly 70 per cent., when the opportunity to become a member of the Association of Engineering Societies presented itself and was accepted, as your Board of Directors believed that by such action a solution of our difficulties would be brought about.

The results have entirely justified the action of the Board, all members being satisfied with the amount and character of the literature and the reduction in expenses and dues, so that at this time our Association is out of debt and has every promise of being able to maintain itself without financial embarassment.

It has been regretted by those who have been accustomed to be present at our regular and informal meetings that more of our members have not accepted the opportunity to present papers or to be present to join in the instructive and pleasant discussions which all who have attended have enjoyed. It is suggested that all members endeavor to attend our meetings, and contribute either papers upon engineering topics or seek information or provoke discussion by submitting, through the Secretary, questions in writing upon such subjects as may come within the scope and intent of the Association.

At the date of our last annual meeting our roll contained thirty-five active and two honorary members, to which there has been added during the past year three active members, the present membership being thirty-eight active and two honorary members.

During the year there have been held five meetings of the Board of Directors and seven meetings of the Association. Six papers have been read and five informal discussions held.

The following statement from our Treasurer's books will show our receipts, expenditures and present financial status:

RECEIPTS.

Cash on hand January 1, 1895, including $140 dues for 1895	$158 52	
Received from initiations	7 50	
Received balance of annual dues, 1895	35 00	
		$201 02

EXPENDITURES.

Paid for entrance fees and dues to Association of Engineering Societies	$127 00	
Stationery and printing	5 00	
Incidentals, postage, etc.	7 95	
Cash on hand January 1, 1896	61 07	
		$201 02

Both the Secretary and the Treasurer deserve the thanks of the Association for the careful and efficient manner in which their duties have been performed.

Respectfully,

J. C. Rawn, *President.*

The election of officers for the ensuing year was announced, and the President appointed as Scrutineers of the ballots, Messrs. C. S. Churchill, H. A. Gillis and M. E. Yeatman, who reported the following as elected:

President, D. C. Humphreys; Vice-President, G. R. Henderson (to serve two years); Secretary, John A. Pilcher; Treasurer, James Schick; Directors (to serve three years), Hermann Crueger, R. A. Marr and J. C. Rawn.

These same Scrutineers were appointed to examine the ballots on the change in Constitution and Rules, and reported as follows:

Change in Article I.—Affirmative 9; negative, 8. Article declared unchanged, since a two-thirds vote is required.

Change in Article IX.—Affirmative, 16; negative, 1. Declared to be changed, and when changed reads as follows:

Article IX—Amendments.

These rules may be amended at any annual meeting by a two-thirds vote of the members present; *provided,* that written notice of the proposed amendment shall have been given at a previous meeting; and *provided* also, that the amendment or amendments so adopted shall be printed upon a ballot and sent, not later than thirty days thereafter, to all members, and each person receiving the same shall be requested to return it to the Secretary with his written vote of YES or NO to each amendment, and his signature; and the President shall appoint as Scrutineers, three members, who shall examine all of the said ballots which shall have been returned within one month from the date of their distribution, and shall report the result; and the Secretary shall publish and distribute to members, not later than the next distribution of printed matter, an announcement of the said result so reported, together with the text of the additional or amended rule or rules so adopted; and the amendment or amendments approved by the majority of the ballots so returned and reported shall become part of these rules from and after the publication of said announcement by the Secretary.

Mr. H. A. Gillis presented to the Association a communication from Mr. L. S. Randolph, calling attention to a bill in Congress, H. R. 3618, for the purpose of increasing the efficiency of the Navy, and asking the Association to take some action in regard to it. On motion of Mr. Churchill to appoint a committee of three

to urge this matter upon the attention of the members of Congress from Virginia, the President appointed on such committee Mr. H. A. Gillis, Mr. C. S. Churchill and Mr. G. R. Henderson.

Mr. Gillis reported a road improvement bill in the Virginia Legislature, and on motion this same committee were instructed to use the influence of this Association to have it passed.

The Secretary reported that he had received, through Mr. Hurley, member of Congress, a copy of Bill H. R. 2758, "To fix the standard of weights and measures by the adoption of the metric system of weights and measures," proposed by him. After much discussion for and against the bill, the matter was on motion laid on the table.

Mr. Wm. M. Dunlap read a paper on "Assessments for Municipal Improvements," which was of much interest, pointing out that none of the simple methods in use, whether by frontage, area or valuation, would be found equitable in all cases, but recommending a combination of two or more of these. The paper brought out considerable discussion, and on motion was referred to the Publication Committee.

On motion of Mr. Yeatman the thanks of the Association were tendered Mr. J. C. Rawn, the outgoing President, for his efficient services during the year, which motion was amended so as to include in the thanks the Secretary and the Treasurer.

On motion of Mr. White the thanks of the Association were voted the Norfolk and Western Railroad for the use of their offices as a meeting place during the year.

John A. Pilcher, *Secretary.*

N. B.—Papers from members on any engineering subjects are desired. Please forward same to Secretary.

List of Officers of the Association.

President—D. C. Humphreys, Lexington, Va.; term expires January, 1897.

First Vice-President—M. E. Yeatman, Roanoke, Va.; term expires January, 1897.

Second Vice-President—G. R. Henderson, Roanoke, Va.; term expires, January, 1898.

Treasurer—James R. Schick, Roanoke, Va.; term expires January, 1897.

Secretary—John A. Pilcher, Roanoke, Va.; term expires January, 1897.

Directors—Hermann Crueger, J. C. Rawn, Roanoke, Va.; R. A. Marr, Lexington, Va.; terms expire January, 1899. C. S. Churchill, H. C. Macklin, Roanoke, Va.; L. S. Randolph, Blacksburg, Va.; terms expire January, 1898. W. W. Coe, H. A. Gillis, Wm. M. Dunlap, Roanoke, Va.; terms expire January, 1897.

Civil Engineers' Society of St. Paul.

St. Paul, Minn., February 3, 1896.—A regular meeting of the Civil Engineers' Society of St. Paul was held at 8.30 p.m.. Fourteen members and five visitors present. After the reading of a few communications requiring no action, President Stevens announced Mr. Archibald Johnson, who displayed the drawings and explained the details of the bear-trap lock gates at Sandy Lake. Lieut. W. A. Jones, U. S. Eng. Corps, followed with suggestions as to the probable application of the bear-trap weir foreshadowed by its use at Sandy Lake. Inexpensive, simple in construction, easily repaired, self-cleaning and almost self-acting, the bear-trap

gate is destined to wide application. The Sandy Lake lock has been in almost constant operation this winter, a temperature of perhaps 30° below zero not having interfered with its work. "With this form of lock, then," said Col. Jones, "might not the Great Lakes be navigated without winter interruption?"

After a short discussion, a design for a society escutcheon, to be used on stationery, etc., was presented and informally adopted.

The Librarian was instructed to procure shelving for current periodicals.

Adjourned at 10.30 P.M.

C. L. ANNAN, *Secretary.*

Engineers' Club of Minneapolis.

MINNEAPOLIS, MINN., FEBRUARY 3, 1896.—The Annual Meeting of the Engineers' Club of Minneapolis was held at 8 o'clock P.M., at the office of the City Engineer, City Hall. Vice-President I. E. Howe in the chair.

The minutes of the previous meeting were read and approved.

The reports of the Secretary, the Treasurer and the Librarian were read and accepted.

Election of officers was postponed to the next meeting.

Mr. G. D. Shepardson was elected as representative of the Club on the Board of Managers of the Association of Engineering Societies.

The future of the Club was informally discussed.

The meeting adjourned to meet on the first Monday in March (2d proximo), which meeting was by motion made a regular meeting for the election of officers. Papers by W. W. Redfield on "Triangulation for the Location of a Tunnel for the Discharge Pipes of the East Side Pumping Station;" by W. R. Hoag, on "Precise Level Benchmarks;" and by A. B. Coe on "Measurements of a Difficult Base Line," were promised for this meeting.

ELBERT NEXEN, *Secretary.*

Engineers' Club of St. Louis.

430TH MEETING, FEBRUARY 5th, 1896.—President Ockerson called the Club to order at 8.30 P.M., at 1600 Lucas Place, with thirty members and five visitors present. The minutes of the 429th meeting were read and approved. The Executive Committee reported the doings of its 207th meeting with the following program of papers for the year:

January 8th—English Railway Practice, Geo. B. Leighton.
January 22d—Underground Electrical Service, E. J. Spencer.
February 5th—Engineering Materials in Compression, J. B. Johnson.
February 19th—An Instrument for Testing Gauges to 500 Pounds, J. H. Kinealy.
March 4th—A New Design for a Stadia Board, O. W. Ferguson.
March 18th—The Testing of Coals, Arthur Winslow.
April 1st—Municipal Engineering, Sub-divisions and Grades, Julius Pitzman.
April 15th—The Maintenance of Bridges, Carl Gayler.
May 6th—The Construction of a Low Crib Dam Across Rock River, J. W. Woermann.
May 20th—A New Cross-Breaking Testing Machine, Malverd A. Howe.
June 3d—Fly Wheels, Herbert A. Wagner.
September 16th—The Galveston Harbor Improvements, W. J. Sherman.

October 7th—Some Notes on the Operation of the St. Louis Water Works Conduit, S. Bent Russell.

October 21—Boiler Efficiency with Low-grade Fuels, William H. Bryan.

November 4th—Steel Frame Construction of High Buildings, Julius Baier.

November 18th—Dredging the Mississippi River, Edward Flad.

December 2d—Annual Meeting, Reports of Officers and Committees.

December 16th—Annual Dinner, Installation of Officers, Address of Retiring President.

The Executive Committee reported with their approval applications for membership from W. G. Comber, Horace Dunaway, and J. L. Van Ornum. They were balloted for and elected. An application for membership was announced from O. H. B. Turner, Civil Engineer with Missouri River Commission.

Prof. J. B. Johnson then addressed the Club on the subject of "Engineering Materials in Compressive Stress." He explained the development of a formula for the compressive strength of a brittle solid, which was shown to be borne out by experiments. He also gave empirical laws for the relative crushing strength of prisms of various relative heights, and for loads on portions of the upper surface. Also strain diagrams for compressive tests on stone and brick masonry, and concrete. The formula in question was originally developed by Mr. Charles Bouton, a fifth-year student at Washington University, and was thought to be original, but was found later to have been arrived at at an earlier date by a German engineer. The paper was illustrated by numerous charts, diagrams, and by photographs thrown upon the screen.

The discussion was participated in by Messrs. Baier, Kinealy, Harrington, Flad, Olshausen and Barth. Adjourned.

William H. Bryan, *Secretary.*

431st Meeting, February 19, 1896.—The Club was called to order at 8.30 p.m. by President Ockerson, at 1600 Lucas Place. Sixteen members and three visitors present. The minutes of the 430th meeting were read and approved. The Executive Committee reported doings of its 208th and 209th meetings, approving the Treasurer's accounts for 1895, and approving the application for membership of O. H. B. Turner. He was balloted for and elected. The resignation of A. M. Lockett was announced.

On motion of Mr. Crosby the Secretary was directed to request the Committee on Library to prepare rules to govern the use of periodicals and books outside of the Club rooms.

Prof. J. H. Kinealy then addressed the Club on the subject of testing pressure gauges to high pressures, explaining in detail the investigations and experiments which he had recently conducted. The pressures were beyond the reach of the ordinary mercury column and special apparatus was therefore necessary. The plan which he had developed consisted in measuring the reduction in volume of an air column which was maintained at constant temperature. The volume decreased exactly as the pressures increased. He had in this way measured pressures up to 675 pounds per square inch.

Messrs. Barth, Freeman, Flad, Ockerson, Crosby, Harrington and Prindle took part in the discussion.

It was thought that the increase of temperature due to compressing the air, the possible absorption of air by the water, and the possible expansion of the tube itself under the increase of pressure, might introduce errors. Prof. Kinealy thought, however, that they were not sufficiently large to vitiate the results.

Mr. Barth showed the Club some curious pieces of steam engine piston packing rings which had evidently gone through a severe experience.

Adjourned.

William H. Bryan, *Secretary.*

Technical Society of the Pacific Coast.

Regular Meeting, held February 7, 1896.—Called to order by President Dickie at 8.30 p.m.

Minutes of January 3d and 17th approved.

After substituting the name of Prof. C. B. Wing for Albert T. Smith on the Timber Committee, John Cotter Pelton was declared duly elected member of the Society.

Propositions for membership were read as follows: Fred W. Wood, Los Angeles, Cal., endorsed by A. M. Hunt, W. F. C. Hasson and Hubert Vischer; Lou G. Hare, Salinas, Monterey Co., Cal., endorsed by Adolph Lietz, per O. v. G., Otto von Geldern and Hubert Vischer.

The absence of Mr. Isaacs from the meeting was explained by letter from Mr. W. G. Curtis, Mr. Isaacs being in Oregon on professional business.

President G. W. Dickie delivered an address upon reassuming the presidency of the Society.

In the absence of Mr. Isaacs, the Acting Secretary was requested to read the paper of the evening, with the view of at least making the members familiar with the subject, which is to be again taken up when Mr. Isaacs is present.

On motion, the discussion of the paper was postponed to the next regular meeting, in order to have Mr. Isaacs present.

Discussion on general lines, particularly with reference to handling materials with grab-buckets, participated in by Mr. Richards, Mr. Wagoner, Prof. Wing, Prof. Soulé and President Dickie.

C. E. Grunsky, *Acting Secretary.*

Civil Engineers' Club of Cleveland.

Meeting of the Civil Engineers' Club of Cleveland, February 11, 1896, at the Rooms, Case Library.

Meeting called to order by the Secretary at about 8 p.m. Mr. Ambrose Swasey was invited to preside. The President afterwards came in and took the chair. Present fifty-three members and visitors. The minutes of the last meeting and the report of the Executive Board were read and approved.

The Committee on Resolutions, regarding the death of General M. D. Leggett, offered the following, through Mr. C. H. Strong, Messrs. Barnett and Holden being absent from the city:

"*Resolved*, that we, the Members of the Civil Engineers' Club of Cleveland, learning with sorrow of the death of our brother member, General M. D. Leggett, desire to express our appreciation of his sterling character, of his worth to our country, our city and to our Club, and of our sense of great loss in his death.

"He was one of the early members of the Club, being elected at the first regular meeting, April 3, 1880.

"We have the pleasure of the memory of his late presence with us and of his

voice in our meetings. We are proud of the honor of possessing his name for so many years upon our rolls.

"We extend to his bereaved family our sincere sympathy."

The resolutions were ordered spread upon the minutes and sent to the family of Mr. Leggett.

The death of Mr. Geo. M. Reid was announced, and Mr. Mordecai read a letter from Mr. E. A. Handy, Chief Engineer of the L. S. & M. S. R. R., testifying to the ability and integrity and worth of Mr. Reid.

The following committee was appointed to draft suitable resolutions: Messrs. E. A. Handy, C. A. Carpenter, A. H. Porter, Jno. L. Culley and James McIntyre.

It was decided that the members of the Club meet at the School House, corner of Central and Case Avenues, and attend the funeral together on Thursday afternoon.

The Committee on the Nomination of Officers for the ensuing year reported as follows:

For President, Chas. S. Howe.
" Vice-President, James Ritchie.
" Secretary, Forrest A. Coburn.
" Treasurer, James C. Wallace.
" Librarian, A. Lincoln Hyde.
" 1st Director, Jno. L. Culley.
" 2d Director, Jos. C. Beardsley.

Messrs. S. J. Baker and D. C. Miller were appointed tellers to canvass the votes for the change in the Constitution, as follows:

Article V, Section 1.—Dues. Strike out "ten" and substitute "five."

They reported later that there were twenty-six votes for and eight against, and the amendment was reported carried.

The President invited the Club to meet at his office in the Garfield Building on Wednesday evening, and proceed together to the Architectural Exhibition on the floor below.

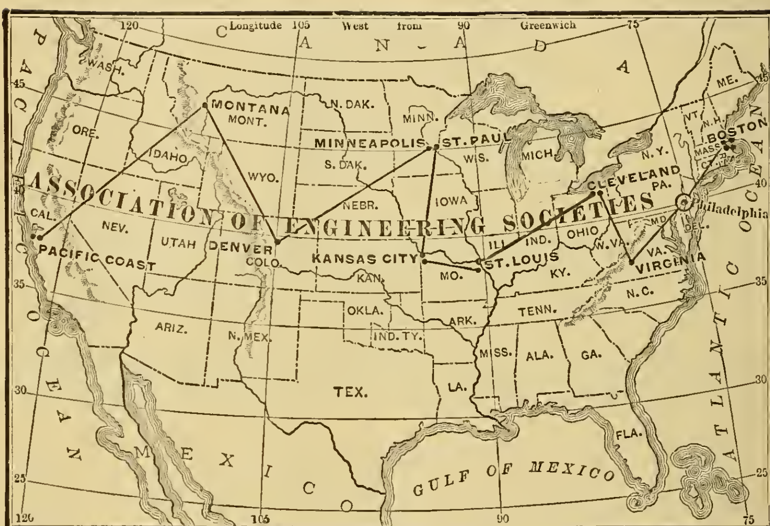
Mr. Rice, the speaker of the evening, then gave an account of the cracking of a large cast iron pipe culvert, and of the settlement of the piers of the Central Viaduct, and the method employed in raising them.

Messrs. Force, Searles, Thompson and others contributed accounts of the failure of various engineering works, and the unreliability of the silt formation of the Cuyahoga Valley was generally testified to.

Owing to the lateness of the hour and to the fact that the lunch was awaiting the Club, the discussion of the Metric System was deferred to a special meeting to be held on February 25, 1896.

Dr. Dayton C. Miller had on exhibition some of the Case School's interesting standards and weights and measures of the Metric System.

F. A. Coburn, *Secretary.*



Bradley & Poates, Engr's, N.Y.

ASSOCIATION OF ENGINEERING SOCIETIES.

VOL. XVI. | MARCH, 1896. | No. 3.

PROCEEDINGS.

Boston Society of Civil Engineers.

FEBRUARY 19, 1896.—A regular meeting of the Society was held at its rooms, 36 Bromfield Street, Boston, at 7.45 P.M., President Albert F. Noyes in the chair. Sixty members and visitors present.

The record of the last meeting was read and approved.

Messrs. James M. Betton, Edwin F. Dwelley, Walter I. Johnson, Hiram A. Miller, John W. Morrison and Sturgis H. Thorndike were elected members of the Society.

The President reported for the Board of Government a recommendation that the annual dues of the Society be increased one dollar, and in accordance with this recommendation notice was given in writing, that the first clause of By-law 10 be amended so that it shall read:

The entrance fee shall be ten dollars. The annual dues shall be eight dollars for members and associates residing within thirty miles of Boston, and five dollars for those residing at a greater distance, payable in advance at the annual meeting. Members elected after September 1st shall pay but one-half the annual dues for that year.

The President read a communication from the Board of Government recommending that George L. Vose be made an honorary member.

The Committee to nominate a candidate for Librarian to fill the vacancy caused by the resignation of Frank L. Locke, reported the name of Alfred D. Flinn, and upon a ballot being taken, he was elected unanimously.

On motion of Mr. Manley the sum of $25.00 was added to the appropriation for the incidental expenses of the annual dinner.

On motion of Mr. Fuller the thanks of the Society were voted to Mr. J. H. Millet, President of the Crosby Steam Gauge and Valve Co., of Boston, for courtesies shown members of the Society on the occasion of the visit to the works of the company this afternoon.

The President appointed Messrs. William B. Fuller and Charles E. Putnam, the tellers to canvass ballots for officers at the annual meeting.

Dr. Theobald Smith, Pathologist of the Massachusetts State Board of Health, was then introduced and gave a very interesting address on the Production of Diptheria Antitoxin.

After passing a vote of thanks to Dr. Smith for his instructive address the Society adjourned.

S. E. Tinkham, *Secretary.*

February 26, 1896.—A special meeting of the Society was held at its rooms, 36 Bromfield Street, Boston, at 8 o'clock p.m., Mr. Henry Manley in the chair. 135 members and visitors present, including ladies.

Prof. Ira N. Hollis gave a very entertaining address, entitled "The Growth of our Modern Navy." At the conclusion of the lecture, Prof. Hollis exhibited and explained a series of about seventy-five lantern slides, showing some of the old wooden vessels of the navy and many of the newer war vessels.

Adjourned.

S. E. Tinkham, *Secretary.*

Civil Engineers' Society of St. Paul.

St. Paul, Minn., March 2, 1896.—Regular meeting of the Civil Engineers' Society of St. Paul, held at 8.30 p.m. Eleven members and two visitors present. President Stevens presided. The Secretary was instructed to accept the Journal of the Western Society of Engineers, and express the thanks of the Society to Mrs. Helen J. McCaine, public librarian, for suggestion as to books. The first vote on amendments to Articles IX and XX of the constitution was unanimously in favor.

A communication from the President of the Western Society of Engineers resulted in the passage of the following resolutions:—

Whereas, a bill known as House Bill No. 1470, dated December 12, 1895, introduced by the Hon. J. Frank Aldrich, M.C., in the first session of the 54th Congress, provides for the appointment of a Commission of Public Architecture to have control of the design and construction of public buildings, and further provides that said commission shall be constituted of three architects and two officers of the United States Army, and

Whereas, the problems entering into the construction of large buildings as to foundations, metal superstructure, heating and drainage, are specifically engineering ones, and are of prime importance, calling for a high grade of engineering ability, therefore, be it resolved by the Civil Engineers' Society of St. Paul, Minnesota, that the Hon. J. F. Aldrich be respectfully requested to so amend House Bill No. 1470 as to provide for the appointment of at least one Civilian Civil Engineer as a member of said Commission of Public Architecture.

Resolved, that our Secretary be directed to forward these resolutions to the Hon. J. F. Aldrich and to the Senators and Representatives from Minnesota.

H. E. Clark and Robert Elden were elected to membership.

Mr. K. E. Hilgard presented some notes on the use of structural steel in railroad rolling stock. Having been employed for some months in applying the principles of bridge engineering to the car trucks of the N. P. R. R. system, with intent to reduce weight, increase strength, simplify parts and debar cast iron and wood, his discourse, fully illustrated by detail drawings, was novel and entertaining.

Mr. Hilgard calculates that the saving in the weight of a car truck amounts to a cent and a half per pound per annum.

Adjourned at 10.30 p.m.

C. L. Annan, *Secretary.*

Engineers' Club of Minneapolis.

Minneapolis, Minn., March 2, 1896.—A regular meeting of the Engineers' Club of Minneapolis, for the election af officers, was held at the office of the City Engineer at 8 o'clock p.m. The President, F. W. Cappelen, in the chair.

Minutes of previous meeting were read and approved.

Letters from John F. Wallace, President of the Western Society of Engineers, enclosing one from Hon. J. Frank Aldrich, M.C., asking to have House Bill 1470 amended by adding civil engineers to the Commission of Public Architecture, were read, and after discussion a motion was unanimously adopted that it was the sense of the meeting that civil engineers should be represented upon the Commission, and our President was directed to write our members of Congress urging them to have the bill so amended.

The following officers of our Club were then elected for 1896:

President, F. W. Cappelen.
Vice-President, I. E. Howe.
Secretary and Treasurer, Elbert Nexsen.
Librarian, A. B. Coe.

W. W. Redfield then read a paper on "Triangulation for Location of Tunnel for Discharge Pipes at East Side Pumping Station."

After informal discussion, this was followed by a short paper by W. R. Hoag, on "Precise Level Benchmarks," illustrated by samples of brass balls, which he has used in this vicinity, and which are inserted in the vertical walls of permanent structures; they are so made that even after their removal from the structure a very close approximation can be made of the original line of the benchmark which has been destroyed.

It was then moved and carried that the reading of A. B. Coe's paper on "Measurement of a Base-line Under Difficulties," be postponed to the next meeting. A paper was also promised by E. H. Loe on "Flour Mill Construction" for that meeting.

The name of F. H. Constant was proposed for membership by W. R. Hoag.

On motion, adjourned.

Elbert Nexsen, *Secretary.*

Engineers' Club of St. Louis.

432d Meeting, March 4, 1896.—The Club met at 1600 Lucas Place, at 8.45 p.m., President Ockerson in the chair. Eighteen members and two visitors present.

The minutes of the 431st meeting were read and approved. The Executive Committee reported the doings of its 210th meeting. Mr. Julius Baier, chairman of the Committee on Library, reported the following rules:

(1) All new books and periodicals shall be kept on the table for one month and shall then be filed.

(2) No book or periodical shall be taken from the Club rooms within one month of its receipt.

(3) No book shall be kept out longer than one month. At the end of that time it must be returned, but may be taken out again, if there is no call for it on record.

(4) Any member taking books from the Club rooms must enter same with date of issue and return against his name in the record book.

(5) Members wishing any book which is out, may place a request on file in a record kept for that purpose, and shall be entitled to the book in the order of the names on the record.

Each of these rules was considered, and voted upon separately, and all were adopted as proposed with the exception of the third, which was amended by the substitution of the word "week" for the word "month."

The paper of the evening, by Mr. O. W. Ferguson, on "A New Design for and Method of Reading a Stadia Board," was read in Mr. Ferguson's absence by Mr. F. B. Maltby. The paper was accompanied by blue prints showing the proposed marking of rod. The author explained the difficulties he had met with, and gave reasons for the remedies proposed. Messrs. F. B. Maltby and W. G. Comber submitted written discussions. The others participating in the discussion were Messrs. Turner, Van Ornum, Jolley and Ockerson.

Attention was called to the fact that the system proposed was not new, but had been tried years ago. Reasons were given why it had not proved desirable in practice and had been discarded. Adjourned.

William H. Bryan, *Secretary.*

433d Meeting, March 18, 1896.—The club was called to order at 8.20 p.m., by President Ockerson, twenty-four members and two visitors present. The minutes of the 432d meeting were read and approved. The executive committee reported the doings of its 211th meeting, recommending that the club endorse the action of the president in writing to certain members of Congress urging that the civil engineering profession be represented on the commission on public architecture, under bill No. 1470, now being considered. On motion of Mr. Russell the Club ratified the action of the president.

Mr. Arthur Winslow then read a paper on "The Testing of Coals," being a consideration of the methods and objects involved in determining the properties and relative values of different coals for all uses, with special references to a series of investigations now in progress by the author. He classified the most important uses of coal as follows: first, steam making; second, coking; third, domestic fires; fourth, gas making; fifth, forge and blacksmith work.

Mr. Winslow's plans contemplate the investigation of all the standard coals of this country, with a view to determining their relative values for the above uses. The methods he proposes to adopt are as follows: first, inspection at the mines; second, collection of samples; third, proximate analyses; fourth, calorific determinations; fifth, laboratory tests; sixth, study of the coal in actual service.

Further investigations in other and special directions will be undertaken as the work develops and necessity demands. Work in the field has already begun, and the investigation will probably extend over a number of years. The author expects to make progress reports from time to time as portions of the work are completed, and he will probably collect all the results in a single publication when the work is completed.

Discussion followed by Messrs. Moore, Meier, Kinealy, Leighton, Bryan, Flad and Russell. The value of calorimeter tests was discussed, as well as the various methods of making such tests.

President Ockerson gave the results of some capacity tests on the new United States dredging boat "Beta," now operating near Memphis.

Col. Meier explained a bill now before Congress looking to the improvement of the standing of naval engineers, and asked the members present to join him in signing a petition to St. Louis Congressmen, commending the subject to their favorable consideration. Adjourned. William H. Bryan, *Secretary.*

Technical Society of the Pacific Coast.

Regular Meeting, March 6, 1896.—Meeting called to order by Vice-President Curtis. Minutes of the regular meeting of February 7, 1896, read and approved.

The following gentlemen were elected to membership by regular ballot: Lou G. Hare, of Salinas, Monterey Co., and Fred W. Wood, of Los Angeles.

Propositions for membership were read as follows: F. S. Edinger, of Berkeley, Cal., endorsed by J. H. Wallace, W. G. Curtis and John D. Isaacs; W. S. Keyes, of San Francisco, proposed by Ross E. Browne, H. C. Behr and Hubert Vischer.

A communication from J. F. Wallace, President of the Western Society of Engineers, Chicago, with enclosure referring to the proposed action by Congress looking to the appointment of a Commission consisting of three architects and two army officers to serve as a Commission of Architecture, and calling attention to the importance of having an engineer on this Commission, was read. The enclosure was a letter to the author of the bill, Hon. J. Frank Aldrich, M.C., Washington, D. C., calling attention to the importance of the engineer's work in modern architecture, and asking for an amendment to the bill (now on its third reading) as above indicated.

Moved by Mr. J. H. Wallace, and duly seconded, that the Secretary be directed to draft a letter substantially on the lines of the letter of Mr. J. F. Wallace, to be addressed to the Hon. J. Frank Aldrich, M.C., Washington, D. C. (and send copy of same to Mr. Wallace, President of the Western Society of Engineers).

Thereupon followed a discussion of Mr. Isaacs' paper on "Modern Coal-handling Machinery," participated in by Mr. Isaacs, John Richards, Prof. Wing, G. W. Percy, Prof. Soulé and Randell Hunt.

Mr. John Richards read a very interesting paper on "Standard Measures," based on a lecture recently delivered by him before the students of the Leland Stanford, Jr. University.

The discussion of this paper was participated in by Prof. Smith, Prof. Soulé, Mr. Percy, Mr. Richards and Vice-President Curtis. Adjourned.

C. E. Grunsky, *Acting Secretary.*

Montana Society of Civil Engineers, Helena, Mont.

At the regular monthly meeting of the Montana Society of Civil Engineers, held in the Board of Trade Rooms Saturday evening, March 14th, the following members were present: Messrs. Cumming, Relf, Keerl, Mumbrue, Taylor and F. J. Smith. The meeting was called to order by Second Vice-President A. E. Cumming.

The applications for membership of John W. Young, of Helena, and John French, of Great Falls, were read and approved, and the Secretary was directed to

send out letter ballots to be canvassed at the April meeting. The ballots for membership were canvassed, and Prof. Frederick C. Scheuch, of Missoula, and Albert J. Seligman, of Helena, were elected members of the Society.

The Chairman appointed James S. Keerl, F. J. Smith and C. W. Goodale as members of a committee upon what is known as the Architects' Bill now pending in the national legislature. The object of this bill is the appointment of five persons as a permanent commission on the design and construction of all public buildings. As the design of modern public buildings involves so many engineering problems, the above committee was appointed to endeavor to secure the proper recognition of the engineering profession upon this commission.

The Secretary read a flattering letter from Prof. J. B. Johnson, ex-President of the Association of Engineering Societies, which read in part as follows: "My somewhat intimate relations with the several societies in the Association have led me to believe that your Society is probably doing a greater work in proportion to its membership than any other society in the Association. I therefore congratulate you on the earnest and helpful policy pervading your Society."

A letter was also read from Col. J. F. Dodge, formerly President of the Society and a civil engineer who had much to do with the first location and construction of railways in this State. He said, among other things: "Please convey to the Society my heartiest greetings and my wishes for its prosperity and the maintenance of the high position in public estimation to which most useful and worthy service entitles it."

Prof. Ryon, of the College of Agriculture and Mechanic Arts, at Bozeman, sent the following letter:

"You will be pleased to learn that the action of the Montana Society of Civil Engineers in advocating proper methods for the measurement of water is now bearing fruit. The agitation of the subject attracted general attention, as might be expected. This active movement on the part of the Society was followed by the publication of our agricultural experiment station bulletin No. 6. You are, of course, aware that considerable opposition was encountered owing to the impossibility of conveying to the public a clear conception of the subject, and that naturally the conservatism of the people defeated the adoption of the measure recommended by the Society—namely, the embodying in our statutes proper laws regulating the measurement of water. Fears were also expressed at the time that the Society had some ulterior designs in the matter, it being difficult for the average mind to conceive of a professional association striving simply for the good of the State without having an axe to grind at the same time. It is therefore with pleasure that I communicate to you the news that the officers of the Farmers' Canal have informed me that they are now satisfied that for economy of installation and for general satisfaction in the results obtained the weir offers every advantage over the statutory inch box, and that they therefore propose immediately to install measuring weirs throughout their system of laterals. As this canal carries 9,000 inches we will have an object lesson which cannot fail to impress all practical men, who look into the matter, with the superiority of this method for the measurement of water; further it will appear that the Montana Society of Engineers has no interest other than the welfare of the State in the matter. The Farmers' Canal Company is one of the most successful organizations of its kind in the State, and this progressive action certainly reflects great credit on its officers."

The letter was gratifying to the members present at the meeting, as it marked the beginning of a new era in the measurement of water in this State. The adoption of the weir measurement of water by such practical men as compose the Farmers' Canal Company is assurance that at no distant date this method of measuring water will be adopted by practical men all over the State, and that the "miner's inch," which means nothing, will be wiped from the Montana statutes.

F. J. Smith, *Secretary.*

Bradley & Poates, Engr's, N.Y.

Association of Engineering Societies.

Vol. XVI. | APRIL, 1896. | No. 4.

PROCEEDINGS.

Civil Engineers' Society of St. Paul.

St. Paul, Minn., March 6, 1896.—A regular meeting of the Civil Engineers' Society of St. Paul was held at 8.30 p.m. Fourteen members and two visitors in attendance. President Stevens in the chair. Minutes of previous meeting were read and approved.

The Constitution of the Society was amended as follows: "To inquire into delinquent dues and assessments" was added after the word "purposes" in Article IX.

Article XX was amended to read: "Any member who does not pay his assessments or dues within a period of one year shall cease to be a member unless the Government, for cause believed by it sufficient, extend the time for payment or accommodate the charges in a manner that it may consider reasonable. The Government shall hold one meeting between the first and fifteenth days of December of each year, and at such other times as the President may select, for the consideration of delinquent accounts."

The By-laws were amended by striking out Section 5 and renumbering Sections 6 to 11 inclusive to read Sec. 5, Sec. 6, Sec. 7, Sec. 8, Sec. 9, Sec. 10.

Mr. Tracy Lyon talked for an hour to good purpose on "The Maintenance of Railway Rolling Stock."

After a short discussion the meeting adjourned at 10.30 p m.

C. L. Annan, *Secretary.*

The Civil Engineers' Club of Cleveland.

Annual Meeting, held March 10, 1896.—President Mordecai in the chair. Present 49 members and visitors. The minutes of the last regular meeting were read, and, after the addition of the article of the constitution as amended, they were adopted.

The minutes of the meeting held February 25th, for the discussion of the metric system, were also read and adopted. The report of the Executive Board, and the applications for membership of Messrs. Green and Sample, were read.

The report of the Committee on Resolutions concerning the death of Mr. Geo. M. Reid was offered and adopted, and ordered spread upon the minutes. The report is as follows:

Resolved: That we, the members of the Civil Engineers' Club of Cleveland have learned with sorrow of the death of our brother, George M. Reid.

Mr. Reid was one of the earliest members of the Club and always took an earnest and active interest in its welfare, and we feel that in his death our Club has sustained a severe loss.

We hereby extend to his bereaved family our most sincere sympathy.

Mr. Swasey and Mr. Benjamin reported progress for the Banquet Committee.

Messrs. Herman and Jewett were appointed as tellers to canvass ballots for the election of officers.

The Treasurer's report was read by Mr. Wallace, as follows:

I herewith submit the report of the Treasurer, for the year starting March 9, 1895, and ending March 10, 1896. There was a balance left from last year of $224 94. There has been collected during the year, dues, $1,234.18, and a percentage of the Cleveland Frog and Crossing Co.'s advertisements in the Journal of the Association of Engineering Societies of $72, making a total for the year of $1,531.12.

Disbursements for this period have been: Rent to Case Library, $75; 135 membership tickets in Case Library at $1 each, $135; Association of Engineering Societies, $651.78 of which amount $120.78 was extra assessments for the year 1894, the balance was the second, third and fourth quarterly assessments for 1896; decorations of the Club room, $126.03; invoices of caterers for lunches after meetings, $73.70; stationery, printing, stamps, etc., $287.78; leaving the total amount disbursed during the year of $1,349.39. This amount deducted from the receipts of $1,531.12, leaves a balance in the treasury of $181.83.

The permanent fund deposit, with the Society for Savings, last year was $338.30, to which has been added for the current year the sum of $65 from entrance fees, and $14.40 from interest, making a total of $79.40 that has been collected to the credit of the permanent fund this year, that added to the balance of last year, of $338.70, leave as balance of $417.70 for the permanent fund.

There has been collected for the Library fund the sum of $210, which is intact, there having been no disbursements from the same as yet.

There are about 28 or 30 members that have not paid their dues for the past year, which, if paid in, with the balance we have on hand, would leave a very nice working balance.

It was moved and carried, that after being properly audited, the report be accepted and placed on the minutes of the Club and published.

The Secretary's report was read, as follows:

The Club now numbers 164 members: engineers, teachers, business men and architects. There are:—

Honorary members	5
Corresponding members	15
Associate members	13
Active members	131

During the year 2 members have changed their names from the active to the corresponding membership roll; 4 persons have been elected to active membership and 1 to associate membership; 14 names have been dropped from the rolls

for the non-payment of the dues of 1894, as called for by the constitution; and 6 have resigned.

And with sorrow do we remember that 3 brother engineers, Mr. A. M. Wellington (formerly a member), General M. D. Leggett, and Mr. Geo. M. Reid, active members, have died.

We have 17 less in number than at the beginning of the year. Last year there was a decrease of 7 only.

It seems as though this slight falling off in membership of the past two years, the only years in which the Club has not gained in numbers, is due chiefly to the hard times and the increase in initiation fees, which have together adversely affected the income of the engineer.

The change in the constitution which was adopted at the last meeting will help, and we hope the coming year will set this matter right, and we will again resume our normal condition of increase.

As for the interest in the Club as shown by the attendance at our meetings, we have had altogether the largest since the Club was organized, the average being $48\frac{1}{6}$.

The labors of the Program Committee have this year resulted in great success. The program made out in the beginning so as to be printed in the yearly register has been followed with but few changes. The topics were of great interest and wide variety, and each meeting has been fine in its way.

Dr. Howe opened the season, April 9th, with his fine exhibition of transits with solar attachments.

Dr. Miller followed, May 14th, in the best attended meeting of the year, with his brilliant exhibition of the polariscope.

Mr. Aborn, of the Cleveland Public Schools, continued, June 11th, with his horse-sense advocacy of free-hand drawing.

Prof. Searles, July 9th, took us over our heads, into the mathematics of a flexible ring, and Prof. Benjamin back into the history of pre-historic man, his weapons and tools and their subsequent development.

Architect Barnum, September 10th, favored us with an æsthetic talk upon Educational Architecture, and October 8th, Dr. Langley gave us the latest facts and figures about the electrical production of chlorine and the disinfection of sewage.

November 12th, Engineer Osborn's solid paper upon solid floor construction for bridges was delivered and discussed.

December 10th, we made the first departure from the program in listening to the complete paper of Mr. De Laval upon the Fly-wheel Pumping Engine.

January 14th, Mr. Walter Miller gave us facts and figures about the latest developments of lake marine engines.

February 15th, Mr. Walter Rice, under the head of "Some Experiences in an Engineer's Practice," gave us some idea of the unreliability of the soil in this Cuyahoga Valley to carry weight.

The last meeting, February 25th, the only semi-monthly meeting, was devoted to the discussion of the metric system of weights and measures.

Dr. Miller's exhaustive exhibit of the workings and the merits of the system was *the talk* of the evening. Everyone was surprised at the progress already made and the advancement in public opinion in this matter. The Club passed resolutions approving the adoption of the system in this country.

The light lunches served at the close of meetings lately have been very pleasant. Their cost for all members of the Club, amounting to less than fifty cents for six lunches, is not a burden, and the opportunity for a jolly good visit together is well worth it.

There have been three excursions during the year: One to Case School, May, 14th, which was remarkable for the amount of rain that fell during the hours of its session; twenty persons present; one July 12th, the picnic to Chippewa Lake, remarkable for the number and value of the prizes awarded for athletic and other events; and one to the Johnson plant, at Lorain, fifty-five members attending. These excursions were also all remarkable for the number of ladies present.

The thanks of the Secretary are due to Prof. Searles for assistance in preparing the index to the constitution; to Mr. Osborn, the previous Secretary, for instructions and initiation into the duties of this office; and to the President for his uniform kindness and attention.

For all of these favors, and for the uniform courtesy and consideration from all the members of the Club, he is truly grateful.

The report was adopted and ordered spread upon the minutes.

Prof. Chas. H. Benjamin, Chairman of the Committee on Program for the past year, introduced his associates, who reported as follows:

Dr. John W. Langley, on Electrical Engineering, reported as follows:

The year has not produced anything startling in the line of electrical engineering, but we have had steady progress on all lines, notably in the lines of electrical railroading. I might note the completion of the great electric engine in the city of Baltimore, also an electrically propelled railroad train, at an average speed of eighty miles an hour, and a contract for the building of several electric locomotives. One marked feature of the year is that the storage battery seems to be returned to favor. It received a black eye here in America some years ago, but it is vindicating itself. It has been used in Europe to carry the heavy loads of the lighting stations. We have, in America, two installations of the storage battery for this purpose, the largest of these is the Edison plant, at New York. That installation is said to be working very successfully, and represents a saving on the plant of about $50,000, as well as a saving in current expenses. The other installation is at Lawrence, Mass. There seems to be no reasonable doubt that the storage battery is to be used for the peak of the load during the heavy lighting between the hours of 4 and 7 in the afternoon. Two important electro-chemical installations have been made in Niagara, one of which is an establishment for the production of aluminum. The Pittsburg Reduction Company was the first customer of the Niagara Company. They have now a contract with them for 4500 H. P. to be delivered incessantly, that is twenty-four hours a day and 365 days in a year.

Closely parallel with this is the installation of the Carborundum Company, moving from Monongahela City, Pennsylvania, to Niagara. Their product is a carbide of silicon made by heating sand and coke in an electric furnace. At a very high temperature the carbon in the coke unites with the silica, setting free the oxygen and combining with the silicon. It is also said that plants for the production of carbide of calcium will be erected at Niagara shortly. In these plants lime is substituted for sand, producing a carbide of calcium. At present this carbide is restricted to the manufacture of the new acetylene, and the commercial outcome of this product is still doubtful. This carbide has not been produced at a lower price than $15.00 a ton, and apparently it cannot be produced commercially for that figure. This would make the acetylene at least $15.00 per 10,000 feet.

Another extremely interesting electro-chemical process is about to be located in Niagara: the invention of H. Y. Castner, an English-American inventor, who has turned his inventive knowledge to a new method of producing caustic soda. Many attempts have been made to manufacture soda from common salt and elec-

tricity. There has never before been known any way to prevent the chlorine, after it is liberated, from combining with the caustic soda at the other end.

Then followed illustrations upon the board.

Mr. J. N. Richardson, on Architecture, reported as follows :—

Nothing of great importance has been done last year in architecture. The tall building is still with us, the latest being the St. Paul Building, in New York City, twenty-five stories high. In Boston the people have legislated the tall building not out of existence, but to a certain quarter of the city. New York is trying to limit the height of buildings proportionately to the width of the street.

There is one type of building coming into vogue, I mean the power building for light manufacturing purposes. Electrical transmission of power has brought about a great change in this type of building. We have a sample on St. Clair Street. It is well lighted and equipped with wire transmission. We are going to have power buildings up town instead of down on the flats where they now are.

Mr. Chas. S. Howe, on Applied Science, reported as follows:—

The subject of applied science in its progress during the past year is very broad. I have selected the subject of the new Roentgen rays, or X rays, for my topic. Notwithstanding so many scientists have been at work, nothing new has been discovered. Prof. Roentgen gives the facts. This discovery is full of interest not only to scientists, but also to the common people. It is interesting to scientists because it gives a ray entirely different from anything that has been known before, and to the world at large because those rays pass through opaque substances. Light is a sensation produced by the multitude of waves in the ether which fills all space. These waves are most of them very small, and the light waves are only about on the average $\frac{1}{50000}$ of an inch in length, and four hundred millions of millions to seven hundred millions of millions pass every second. The shorter rays are called the violet end and the longer rays the red end of the spectrum. These produce the effect of light by which we see. Heat and electric rays will pass through substances totally opaque to light. Electric rays will pass through many substances that light cannot pass through. An electric wave is a very long wave, whereas a light ray is short. So the question of passing through substances opaque to light is not new to the scientific world.

Roentgen, in his article, stated that while he was at work with a Crooks tube covered with black paper, he found that by holding a sheet of paper covered with a fluorescent material, the rays of the tube passed through the air and affected the fluorescent material at some distance. He then held some opaque substance between the tube and the fluorescent paper, and it was still fluorescent. He then put a book of 1,000 pages between, and the rays passed through. Then he held his hand between the tube and the fluorescent material, and obtained a shadow of the bones in the hand upon this fluorescent material. Then he placed a photographic plate in the holder covered with a slide, where he had formerly had the fluorescent material, and put some substances between the tube and the plate, and after a certain length of exposure the shadow of the picture was developed. He found that those rays could not be refracted, that they passed through all substances, that nothing seemed to stop them. Certain things are more permeable than others. These rays will pass through wood easier than through glass. Glass, which is transparent to light, is more or less opaque to these rays. They pass through the denser metals with greater difficulty. These rays cannot be bent. The only thing we can do is to make a shadow picture, and the shadow of the substance is developed upon the plate. It is entirely different from ordinary photography. Prof. Roentgen then tried to reflect the ray to see if anything would turn it from its course by reflection. He was

wholly unable to reflect it. He thought possibly he had succeeded in refracting and reflecting these rays to a slight extent, but he was not sure of it. A substance in the form of a very fine powder ordinarily does not pass light through. The fine particles of matter reflect the rays of light in every direction, and none go through powder with as great ease as they do through the metal of which the powder was made. The X rays pass through the powder as easily as through a solid. Then he tried to polarize the rays, but they are not subject to polarization. He has suggested that the rays may be longitudinal, instead of transverse.

Dr. Dayton C. Miller, on Roentgen Photography, reported as follows :—

I think probably it would be interesting to the Club to exhibit a few photographs and let you judge of the results of the Roentgen photography for yourselves. The first thing we tried, four weeks ago, at Case School of Applied Science, was to photograph a coin placed on the outside of the box which contained the sensitive plate. After an hour's exposure this picture was made. It shows an indistinct outline of the coin upon the plate.

In the work at the college we became more interested in the practical application than the theoretical part of the subject. Of course, we are interested in the theoretical part, but we want to know what it is and what it will do before we begin to theorize about it. We have photographed the bones of the fingers just as Roentgen has. Afterward we placed opaque bodies, such as keys and rings, under the fingers and obtained photographs with an outline of these articles through the hand. Next, we determined whether foreign substances in the hands could be detected, as well as deformation of the bones. We experimented for a time by placing bullets under the hand, and the bullets have been shown with perfect ease. One of the most difficult experiments was photographing through the foot with the bullet placed under the heel, and we succeeded in obtaining an image of the bullet in five minutes. After having photographed these bullets, we found some real subjects who had bullets in their hands. One is a gentleman in the *Leader* printing office, who shot himself while a boy, the ball entering the palm of his hand and going toward the wrist. He has always supposed that the ball was located in the arm between the wrist and elbow. The arm was photographed from the wrist to the elbow. The picture developed with perfect distinctness, but we did not find the bullet. Then we photographed the hand, and the first photograph indicated a very suspicious spot; the second photograph indicated a small ball at the bottom of the little finger. This gentleman was once a type-setter, and he had to give up the business because it caused him such pain, and it was because the ball irritated the nerve. Another picture is the Marshal of New Philadelphia, who has a bullet in the back of his hand. The doctor probed for it and was unable to locate it. Five photographs were taken, and every one located the bullet in exactly in the same spot, where the thumb joins on to the wrist bones, and the bullet will now be extracted. These are the only surgical cases we have undertaken so far. Among the better pictures which we have taken more recently is one of an aluminum medal, which shows the letters very distinctly.

The thicker parts of the human body have not as yet been tried. It takes too long a time. The photographic plate is placed in an ordinary box in which it is carried around for taking pictures. The plate is never uncovered in that box, so that there is no possibility of the plate becoming light struck. A pasteboard box offers no resistance to the rays. The hand, when photographed, is strapped to the plate holder, in order that the bones may be brought as close to the plate as possible. The earlier exposures varied from one to three hours. Our present expos-

ures vary from nothing to twenty minutes. A bullet has been located in eight minutes. We have secured an image of the ends of the fingers in thirty seconds with which it was possible to obtain an outline of the bones. The arm to be photographed having been strapped to the plate, a Crookes tube is placed above the kathode pointing towards the arm which is to be taken. The tube consists of a globe of glass made cylindrical or spherical, exhausted to a very high degree. The coil in use discharges sparks six inches long. It looks like a small streak of lightning; as the tube is more and more exhausted the spark changes into a broad band and grows larger till the inside of the globe is all aglow. Then still further exhaustion causes the glow to lessen, and the tube becomes fluorescent. It is supposed that the pressure is only about $\frac{1}{1000000}$ of an atmosphere inside of it at that time, and that the particles which strike the kathode become charged and are repelled from it, and that those particles in being driven away from the kathode have a chance to move to the other side of the glass before striking anything. That part of the glass becomes so hot one cannot hold his finger on it, and it can be made so hot that it will break the glass. The whole globe is more or less fluorescent. The light is a sort of a greenish-yellow color, always moving and shivering, very much like the Northern light. In order that one may see it, the room must be darkened, although darkness does not aid in the experiment. An English physicist named Crookes was the first to experiment with the phenomena of discharge in a high vacuum, and his tubes are called Crookes tubes, and they have been used in these experiments. The induction coil is the same which is familiar to you all. It is excited by eleven cells of storage battery, but it may be excited by a Grove battery. There is a peculiarity about the photographic plates in that "slow" plates seem as sensitive to these rays as the "fastest" plates. A lantern slide plate is nearly as sensitive to this work as the lightning plates used for snap shots!

Mr. H. H. Porter.—Can you make a shadow from an object some distance from the plate?

Dr. Miller.—Yes, but the shadow would be more indistinct. It would be a mere umbra. The rays start out perpendicular to the surface of the glass, and it has been supposed that they originate on the fluorescent glass. That may not be true. It hardly can be demonstrated.

Mr. Richardson.—Does the positive electrode or anode make much of a picture?

Dr. Miller.—It has been stated that the anode is the only important quantity, but others think it is the kathode. All our experiments point to the fact that it is the rays which strike out from the kathode which give direction, but I think the anode has something to do with it.

Professor Benjamin himself, on Mechanical Engineering, gave the following report: One of the most interesting developments in the use of steam is found in the use of high pressure steam. In Cornell University, experiments are made with steam 500 to 700 pounds to the square inch, and they have succeeded in obtaining greater efficiency than is possible with steam at lower pressure. They intend carrying those experiments still farther. The subject of determining the moisture of steam has been investigated, and it has been found that all calorimeters, as usually applied, are practically worthless and entirely misleading. The calorimeter is not at fault, but it is impossible to collect a fair sample of the steam.

The increase in the number of fly-wheel accidents has been marked the last two years. A gradual change is being made in this kind of construction, and the number of steel wheels is increasing.

With the subject of smoke prevention you are all familiar. There is no difficulty whatever in preventing smoke. There are eight or ten different stokers in the market, but it still requires a certain amount of brains to operate them, and the only way to prevent smoke, besides getting a mechanical stoker, is to pay more than a dollar a day for a fireman. There is one great fallacy prevalent, and that is that a boiler with a stoker cannot be crowded. It is not necessary to limit the capacity of the boiler when a stoker is applied. The other day we evaporated steam (equivalent to 100 horse-power from a 50 horse-power boiler) without any smoke, and we could do that night and day, except at such times as it is necessary to clean the grates at the bottom. You cannot see that there is any fire in the boiler from the appearance of the chimney. It is our intention this year to push these experiments not only in the school, but elsewhere.

In machinery, one of the principal developments is the increased use of the milling machine, which is gradually superseding the planer. The use of electricity in shops as a motive power is becoming more common. The Baldwin Locomotive Works have expended 75 per cent. of their gross power in running their shafting, and they have, to a considerable extent, replaced their shafts by wires. There is considerable progress in this direction, especially in shops where the works extend over considerable space of ground, and in separate buildings. We have two students this year engaged in going around among establishments in this city to determine the relative consumption of power by the actual work done. It shows that in many cases the introduction of electricity would be a saving, and in other cases it would not be advisable. It depends on location.

The general tendency in mechanical engineering and manufacturing seems to be towards studying more carefully the minor economies. As competition becomes more keen, and especially during these hard times, men have learned not to despise small things, and they devote more of their time and education to tying up the little loose ends.

All these reports were accepted and ordered spread upon the minutes.

The report of the Librarian was read as follows:

The Association of Engineering Societies has been decreased by the withdrawal from the same of the Western Society of Engineers. The cost of publishing the Journal has been cut down so as to keep it within the $3.00 limit. This has been done by cutting out the Index Department and by condensing reports of proceedings as much as possible, cutting down discussions, and in every possible manner reducing the cost of publication.

The Association elected S. E. Tinkham, of Boston, Chairman, and John C. Trautwine, Jr., Secretary for the ensuing year.

The Library of the Club has been reorganized and will in future be a credit to the Club. A contract has been entered into with Case Library by which the library will care for our books and pamphlets the same as their own; they will expend, annually, in the purchase of engineering books, the same amount as we subscribe, and the result must be a very valuable collection. The purchases will be made by a joint committee consisting of the Library Committee of the Club and the Librarian of Case Library. The Club has already subscribed $210.00 for this year, and has agreed to continue the subscription annually for five years. This enables us to purchase $420.00 worth of books this year. Half of these belong to the Club, and are stamped with the Club's stamp, and the other half to Case Library, and the Club may remove its share in case of the severing of the present relations with the Library.

This condition has been arrived at principally through the efforts of Mr. John L. Culley, who first suggested the subscription, and who carried the matter to a successful conclusion.

The report was received and ordered spread on the minutes.

The annual address of the retiring president was read as follows and accepted and ordered spread upon the minutes.

ANNUAL ADDRESS
BY
PRESIDENT AUGUSTUS MORDECAI.

I do not think that we can be considered vainglorious if, for one evening in the year, at least, we should review for a moment the achievements of the Civil Engineer, and consider, somewhat boastfully perhaps, what he has accomplished in the world's progress, and to how great an extent the members of modern communities are indebted to him for the means of carrying on their various occupations, and for the comfort and well-being of their daily lives. Civil engineering is essentially a profession of peace and civilization. Amongst the most savage tribes of Africa or Patagonia you will find always the Military Chieftain, the High Priest, and generally the Medicine Man, but it is only in the more advanced tribes that anyone having the smallest resemblance to the Civil Engineer can be discerned. It is amongst those communities that have made the greatest progress and that are characterized by the highest intelligence, that the Civil Engineer finds his most favorable environment, No other profession has made such advances in recorded times. The ideas of a God one and indivisible and of vicarious atonement, the cardinal principles of modern theology, are clearly set forth in the Book of Genesis, one of the earliest historical records we have. The laws enunciated with such sublime effect on Mount Sinai contain nearly the whole principles of criminal jurisprudence, as those afterwards given by Moses of civil jurisprudence. The marshalling of the children of Israel into companies of fifty and companies of one hundred, and the subsequent campaigns of Joshua, show well-developed germs of discipline, tactics and strategy; and while it may be true that germs of the modern blast furnace, more or less microscopic, can be discovered in Tubal Cain's forge, yet nowhere can be found any discoverable protoplasm of the modern applications of the forces of steam and electricity. Does not the very application of the term "learned," to some of the other professions, go to show that to be thoroughly versed in them, it is necessary to study the language, manners, laws and customs of people now scattered and lost?

In the Jewish Talmud, that mine of apt parable, there is told a story that runs somewhat in this wise:

When Solomon had finished building the temple, he gave a feast to the principal officers who had helped him, and the one who had done the most toward the work, or who represented the most useful craft, was to occupy a seat of honor on his right hand. The company, after assembling, was to choose who was to be thus distinguished. When, however, the guests came to the banquet hall, what was their surprise to find an humble Blacksmith seated in the seat of honor. Solomon, provoked, asked the Blacksmith why he was there. "Did he not know that the chair was to be occupied by the one who had done the most in building the temple," and turning to his guests asked if they knew him. He who carved the Cherubim said: "This is no Sculptor; I know him not." He who inlaid the roof with gold said: "Neither is he of those who work in refined metals." He who worked on

the walls said : "He belongs not with those who are cutters of stone." And he who shaped the timbers said: "We who are skilled in framing and joining know him not." The King turned to the Blacksmith, who, nothing daunted, said: "But, O King, who made the fine chisels that the sculptor used, or the sharp knives and saws of the framers in wood, or the tools of the metal worker, was it not the Blacksmith? When they wish to deride me they call me a 'Blacksmith,' when they wish to praise me, they call me 'Son of the Forge,' but what would they do without my labor first?" Said Solomon, wise man that he was, "You have spoken truly, O 'Son of the Forge,' and you can keep the seat to which you are entitled and be our guest." "Thus," said the Rabbis, "Solomon acknowledged the dignity and importance of labor," and so may we not say to our military brother, waiting for "the cobwebs to be brushed from the cannon's mouth,' to find how good is his work and dreading all the attendant horrors, what could you have done if it were not for the tools we have placed in your hands; to the Physician, how could you have checked disease were it not for the pure water and ample drainage systems that we have given you; to the Surgeon, what could you have accomplished without the fine instruments that we have rendered possible, and so on through the list.

It is the misfortune of the Civil Engineer that he is an agent and works through agents. His achievements are produced, not by personal intercourse, but through his agents, and he is obliged to have financial means to carry out his plans, so that often his efforts are overshadowed by the financier on the one hand and the contractor on the other, and yet, it is his knowledge and experience that we must depend upon for our safety, comfort and happiness. Fortunately, all of us are not ill all the time, nor are we always in need of spiritual or legal advice, but every one of us, from the time of using the water spigot in the morning, immediately after rising, to the time of turning off the gas or electricity, immediately before retiring, depends upon the skill and experience of the Civil Engineer, shown, not by personal contact, but by ever-present results. Another misfortune he labors under is, that the result of one man's efforts is shared by thousands. Every one obtaining the benefit of his work does not have to come in personal contact with him, and his failures as well as his successes are immediately apparent. Of the hundreds of thousands of people, for instance, who cross the Brooklyn Bridge every day, all know the name of the Doctor they consulted last year, perhaps; of the Lawyer who tried a celebrated case last week; many know the name of the gallant soldier who commands Governor's Island on their left, or that of the brave admiral who heads the navy yard on their right; but I venture to say there are few who remember the name of the talented engineer who built the bridge, and few, very few, that of the skilful and accomplished gentleman by means of whose knowledge and experience they are enabled to cross every day so rapidly and safely, and I am afraid there are very few in this room, Civil Engineers as we are, who could name him.

It was only after the true principles of the correlation and the conservation of forces were discovered and understood, that the advances in the result obtained took such wonderful strides. As soon as man gave up the idea of being equal to his Creator, and learned that forces never die, but that they are perpetual, only taking different forms, and that they are related one to another; that heat meant motion and motion could be turned into power through steam and electricity; and that power could be directed in endless ways and accomplish nearly endless results, the wonderful advances of the last one hundred years took place. When he ceased to be an alchemist and became a chemist, what a list of achievements must be credited to him!

If Civil Engineering is "the art of directing the great sources of power in nature for the use and convenience of man," go where you will, turn which way you please, you see evidences of the handiwork of the Civil Engineer. It would take 30,000,000 camel loads to transport the tonnage of the city of Cleveland alone for one year; it would take a month for a camel, with 1,000 pounds on his back, his usual load, to go from Cleveland to New York; it would require a bucketful of water to be lifted three times a minute, day and night, from 2,000 wells, to supply the wants of this city alone, and so we might make endless striking comparisons.

The advance is so enormous that it is hard to realize. Certainly, no other profession can show such achievements, and the names of Pontius, Michael Angelo, Watt, Fulton, Stephenson and Edison should shine with equal lustre with those of Galen, Harvey, or Pasteur, St. Augustine, Luther or Wesley, Cicero, Blackstone or Marshall.

"But," says the critic, "you are degenerating. We see many evidences of the works of the architect, the road maker, the bridge builders, etc., of 1900 years ago. Where will most of your work be 1900 years hence, when the earthquakes and the fires and the storms have had a chance to wreck them? Will the New Zealander, so dramatically pictured by Macaulay, have any remains of London Bridge to sit on, or will any ruins of St. Paul be visible to him? The modern work of which you boast is slight, flimsy, ephemeral." Perhaps so, but how admirably adapted for what it has to do; as admirably adapted for its work in this stirring, changing (because progressive) age, as the Coliseum, the Pantheon, the bridges across the Tiber, Alexander's Aqueduct and the Appian Way were in those days. We are not called upon to build huge amphitheaters for witnessing fights of savage beasts; or temples to all the Gods; to carry water by gravity, alone, hundreds of miles; to erect stone bridges, which, by their mass alone would stand; or roads for light chariots; or camels or horses for the use of but one great community; but we are called upon to erect numerous churches to the one God; comfortable homes for all; office buildings for the accommodation of the greatest number at the least expense; pumping engines which have a capacity sufficient not only for the use but for the abuse of millions of people; bridges of iron and steel so admirably proportioned that not a pound of metal is lost; roads for heavy travel or for thundering locomotives, traveling with the greatest rapidity, hauling long trains of cars loaded with every conceivable product of the soil, the mines and the manufactories, from every nook and corner of the world; or palaces, carrying conveniently and luxuriously, delighted passengers; literally for the use of thousands of communities of greater population than the old city of Rome.

Conditions have changed and our work has changed to meet them, and we have brought just as much knowledge and learning and thought to the task, and our individual achievements have been just as good and glorious in their way as those of our professional brother at any time in the world's history, and it is the recognition of this fact, and of the extent to which they are indebted to the skill, perseverance, knowledge and experience of the Civil Engineer, that we should impress upon all, and this is one of the reasons why we should encourage Societies and Clubs, such as this.

We have had a fairly prosperous year, but there are many in the city whom we ought to have with us and draw into our membership, and we should see if we cannot attract them in some way, either by the excellence of our papers on subjects of current interest, or by the knowledge to be gained in the discussion of those sub-

jects in which many are interested, showing the experience of others and helping to solve some knotty problem; perhaps also by the toothsomeness of our lunches, fostering sociability and acquaintance among the members.

I know it is the wish of many members of the Club that we should have rooms of our own, and so far as our membership and income will allow, it certainly would be desirable. Though we have had a standing committee on the question, they have failed to report during the year, but I hope they have accomplished something. It might be possible to associate ourselves with some of the affiliated societies in the city looking towards leasing rooms; or perhaps some advantageous arrangement might be made with the owners of some of the new blocks that are now being erected, or of the old ones vacated. Our income has been too small to accomplish much, but it is a question whether we should not be more ambitious, try to make the social feature, especially for the younger members, a little more prominent, and whether we cannot now afford to spend more and have our own rooms better adapted for Club purposes, even if we continue our present arrangement with the Case Library for our meetings.

Much to the regret, certainly of the Clubs having a smaller membership, the Western Society of Engineers withdrew during the year from the Association of Engineering Societies. It is one of the Clubs having a large membership, and it is unfortunate, I think, that they should consider that their best interests lie outside of the Association. "In union there is strength," and it would seem that if we could have a journal for a number of societies, instead of a journal for each separate society, it would be much to be desired. Since the Western Society has withdrawn it has largely increased its advertising patronage, showing how much more effective work can be done for a local journal than for an associated journal, unless some one especially appointed gives his time to it. If a proportional amount of patronage could be obtained by each of the different clubs in the Association, the Journal could be made a really valuable periodical, and I see no reason why this should not be done by energetic and persistent efforts.

Our membership has been decreased by the deaths of Messrs. Leggett and Reid. We did not see as much of General Leggett as we all wished, as he was a very busy man, with his time fully occupied. No words of mine can add to his record as a brave and gallant soldier, a learned and wise counselor, an accomplished and honest gentleman. Of Mr. Reid we saw more, and we learned to respect him for his knowledge and experience, and to esteem him for his many sterling qualities. He was a faithful and honest employee of the Lake Shore and Michigan Southern Railway Company for many years, and his work testifies to his ability and usefulness. With all he had a kindly and appreciative nature which endeared him to his many friends, and we shall miss him in the Club.

In closing and turning over to my successor the office with which you have so kindly honored me, I can only thank you for the honor and wish you a prosperous and profitable year.

The report of the tellers on election was read as follows:

President—Chas. S. Howe.
Vice-President—James Ritchie.
Secretary—Forrest A. Coburn.
Treasurer—Jas. C. Wallace.
Librarian—A. Lincoln Hyde.
1st Director—John L. Culley.
2d Director—Jos. C. Beardsley.

After some brief remarks by the newly elected officers, the meeting adjourned.

MEETING, April 14, 1896.—President Howe in the chair. Present, fifty-seven members and visitors. The minutes of the Annual Meeting of the Club were read and approved. Messrs. Palmer and Oliver were appointed tellers to canvass the ballots of B. L. Green and J. H. Sample for active members.

The Executive Board reported the resignations of three members and the transfer of two from active to corresponding membership, and the approved applications of nine persons for membership. Letter from E. S. W. Moore, at Wolverhampton, England, late of this city, was read. Also various communications from D. H. Hurley and others, from Washington, in regard to the Metric System.

The topic of the evening, "Smoke Prevention," was first taken up by Prof. C. F. Mabery, who was followed by Prof. C. H. Benjamin. They were followed by various other members, the conclusions arrived at being that in avoiding smoke is was necessary to have sufficient boiler, grate and stack capacity, and to have, on the part of the fireman, sufficient mental capacity. Mechanical stokers and shakers were recommended as a saving both in labor and fuel.

The Program Committee reported as follows:

May 12.—*E. A. Sperry:* Steam Engine for Direct Connected Electric Generators.

June 9.—*Dr. C. O. Arey:* Water Supply and Sewerage as affected by the lower Vegetable Organisms.

July 14.—*James Ritchie:* Inspection of Structural Steel from the Standpoint of the Engineer.

Aug. 11.—*J. D. Varney:* Solar Work in Land Surveying and a New Mechanical Method for Doing it.

Sept. 8.—*J. N. Richardson:* A Paper on Architecture.

Oct. 27.—*C. L. Saunders:* Gas Producers and the Mechanical Handling of Fuel for same.

Nov. 10.—*J. R. Oldham:* Structural Strength of Ships; Efficiency for Repairing without Diminution of Strength.

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Jan. 12.—*Prof. S. H. Short:* Some Problems in Street Railroading.

Jan. 26.—*J. R. Oldham:* Steamship Propulsion and Analysis of Skin Resistance at Deep and Shallow Draught.

Feb. 9.—*Prof. C. H. Benjamin:* Use of Electric Motors on Machine Tools.

Feb. 23.—*Dr. Cady Staley:* A Paper on Sanitary Engineering.

Mar. 9.—*Annual Meeting:* Address by the President.

April 13.—*Dr. Cady Staley:* A Paper on Architecture.

The Standing Committees for the year were announced as follows:

Finance Committee:

Jas. Ritchie,
F. A. Coburn,
Jos. C. Beardsley.

Library Committee:

A. Lincoln Hyde,
John L. Culley,
Jas. C. Wallace.

Program Committee:

Wm. H. Searles,
J. R. Oldham,
Dayton C. Miller,
S. T. Dodd,
C. E. Schulz,
J. G. Oliver,
F. S. Barnum.

After the meeting, the Club repaired to the neighboring restaurant and enjoyed a visit and lunch.

F. A. COBURN, *Secretary.*

Engineers' Club of St. Louis.

434TH MEETING, April 1, 1896.—President Ockerson called the Club to order at 8.15 P.M., at 1600 Lucas Place. Thirty members and eight visitors present.

The minutes of the 433d meeting were read and approved. The Executive Committee reported the doings of its 212th meeting. An application for membership was announced from Mr. Albert Borden, of the engineering department of M. S. Cartter & Co.

Mr. Julius Pitzman then read a paper on "Municipal Engineering," his address having special reference to the laying out of grades and subdivisions, and of parks and public places. The address was illustrated by numerous maps and diagrams indicating the character of grades already established in St. Louis, and the serious mistakes which had been made in this work. Each plat also showed the grade which, in the speaker's opinion, should have been adopted. The enormous money losses due to these mistakes were also shown. Particular emphasis was laid upon the artistic features of the question, in order that the beauty and symmetry of our thoroughfares might be preserved. The essential features underlying the design of parks and boulevards were touched upon. The mistakes already made in our grades were, of course, beyond remedy, but the author deemed it necessary to impress upon all good citizens the importance of avoiding similar errors in the future. He called attention to places where similar mistakes would in all probability be made in the near future unless proper steps were taken to prevent.

Messrs. Robert Moore, Ockerson, R. E. McMath, Macklind, J. B. Johnson, and Spencer took part in the discussion, which was, on the whole, favorable to the speaker's ideas.

It was clearly brought out, however, that many difficulties surround the problem, and that the engineer could not always carry out his ideals, but must do the best he could within the limitations imposed upon him. Adjourned.

WILLIAM H. BRYAN, *Secretary.*

435TH MEETING, April 15, 1896.—President Ockerson called the Club to order at 8.35 P.M., there being twenty-nine members and five visitors present. The minutes of the 434th meeting were read and approved. The Executive Committee reported the doings of its 213th meeting, approving the application for membership of Albert Borden, of the engineering department of M.S. Cartter & Co. He was balloted for and elected. Applications for membership were announced from E. R. Fish and H. C. Meinholtz.

On motion it was ordered that the thanks of the Club be extended to Mr. Estill McHenry for presenting to the Club a number of very valuable photographs, maps, and drawings, formerly belonging to the late Capt. James B. Eads. Ordered, that the Secretary express in a formal letter to Mr. McHenry, the Club's appreciation of the donation. Ordered also, that proper acknowledgment be made to Col. E. D. Meier for donations of the back proceedings of the American Institute of Mining Engineers.

On motion it was ordered that a committee of three, with the President as chairman, be appointed to co-operate with the local members of the American Society of Mechanical Engineers, for the entertainment of their coming convention,—the members of this committee not to be members of the American Society of Mechanical Engineers. The President announced that he would appoint the committee later.

President Ockerson, having to leave at this time, called Mr. B. L. Crosby to the chair.

Mr. Carl Gayler then read a paper on "Highway Bridges." He reviewed briefly the movements in the direction of reform which had heretofore taken place, particularly the agitation of 1890, and gave his views as to why those movements had accomplished so little. He explained a typical case of highway bridge design, and described an accident to the Broadway bridge over the River Des Peres, in South St. Louis, where a contracted water-way had resulted in scouring out a deeper channel, and undermining one of the abutments. He thought it proper, in designing highway bridges, to use lower unit strains than is customary for railroad bridges, rather than higher, as is the general practice. In general, railway bridge practice could, in his opinion, be followed to advantage in highway work. He also discussed lateral top bracing, painting, and inspection.

Messrs. Eayrs, J. B. Johnson, Pitzman, Crosby, French, Russell and Baier participated in the discussion. Adjourned.

William H. Bryan, *Secretary.*

Technical Society of the Pacific Coast.

Regular Meeting, April 3, 1896.—Meeting called to order by Vice-President Curtis. Minutes of meeting of March 6, 1896, read and approved.

The following gentlemen were declared elected to membership by regular ballot: F. S. Edinger, Inspector of Bridges, Berkeley, Cal.; W. S. Keyes, Mining Engineer, San Francisco, Cal.; Russell L. Dunn, Mining Engineer, Auburn, Placer Co., Cal.

A letter from the Metrological Society, New York, was read, calling attention to the bill favorably acted on by the Committee on Coinage, Weights and Measures, House of Representatives, making use of Metric System obligatory after certain dates. Attention was called to the importance of vigorously endorsing the measure.

G. W. Percy moved that the Secretary be directed to address a communication to our Representatives in Congress asking for a support of the measure to make the use of the Metric System obligatory. Carried unanimously.

Mr. Reece, of the American Society of Civil Engineers, then addressed the Society on the subject of "Recent Improvements in Maintenance of Way."

Discussion of Mr. Reece's address was participated in by Mr. J. H. Wallace and Vice-President Curtis.

Mr. Randell Hunt read a paper entitled "Principles Governing the Design of Foundations for High Buildings."

The discussion of this paper was participated in by Prof. Marx, J. H. Wallace, G. W. Percy, Prof. Wing, Prof. Soulé, D. C. Henny, John B. Leonard and Vice-President Curtis. Adjourned.

C. E. Grunsky, *Acting Secretary.*

Association of Engineers of Virginia.

The regular informal monthly meeting of the Association was held April 15, 1896, with President D. C. Humphreys in the chair. H. R. Bill 7251, to fix the standards of weights and measures by the adoption of the Metric System of weights

and measures was taken up and discussed. On motion, the Secretary was instructed to get at once a letter-ballot from the members of the Association, as to whether they favor the passage of the bill, or not, and to inform the Senator and Representatives of our State of the result.

Senate Bill 2301, to establish engineering experimental stations in connection with the colleges established in the several States, under the provision of an Act approved July 2, 1862, and acts supplementary thereto, was taken up and discussed, and, on motion, the Secretary was instructed to get the opinion of the members by letter-ballot, and to report results, as on H. R. Bill 7251.

H. R. Bill 3618, to organize and increase the efficiency of the personnel of the Navy; to increase the usefulness and numbers of the Corps of Naval Engineers; to induce the scientific institutions to provide a naval-engineering reserve for time of war; to establish a naval-engineering experimental station, and to encourage the study of the mechanic arts and sciences, and particularly that of naval engineering, in the technological colleges of the country, was taken up and discussed, and, on motion, the Secretary was instructed to proceed as with the other two bills.

The subject for the evening, "Engineering Ethics," was called and opened by Prof. L. S. Randolph, of Blacksburg, who showed clearly the necessity for some code, as well as the difficulties of making and enforcing it. The discussion was very generally entered into by those present, all seeming in favor of establishing some standard for the guidance as well as for the protection of the profession.

The directors have decided to have the Summer meeting at Pulaski, Va., June 26th and 27th. Detailed information of arrangements will be furnished later. The entertainment committee desire papers from the members. Send subjects to the Secretary.

ROANOKE, VA., April 16th, 1896. JNO. A. PILCHER, *Secretary.*

Montana Society of Civil Engineers, Helena, Mont.

AN adjourned meeting of the Montana Society of Civil Engineers was held Saturday evening, April 18th, in the Society's rooms in the Granite Block. There were present W. A. Haven, Finlay McRae, F. J. Smith, James S. Keerl, A. E. Cumming and James M. Page.

The application for membership of Abram L. Jaqueth, city engineer of Kalispell, was read and approved, and the Secretary was directed to send out ballots to be canvassed at the May meeting.

James S. Keerl and A. E. Cumming were appointed tellers to canvass the ballot for admission to membership. Upon the result being announced the chairman declared that John W. Young, of Salt Lake City, and John French, of Great Falls, had been elected.

Mr. Keerl, of the committee appointed to attempt to secure an amendment to House Bill No. 1470, to include the appointment of at least one civil engineer upon a national commission to supervise the design and construction of public buildings, reported that the matter was progressing satisfactorily, and that he believed the bill would be so amended that the commission would consist of the supervising architect, two civil engineers and two architects. That was encouraging, and Mr. Keerl was directed to continue to exert his influence to that end.

A letter from Gen. W. A. Haven, resigning his position as trustee of the So-

ciety, owing to the fact that he will in a short time remove from the State, was read. Numerous regrets were expressed that one who had done so much to advance the interests of the Society and the profession generally was about to leave. The resignation was accepted, and a committee consisting of Messrs. Keerl, Herron and Page, was appointed to draw up fitting resolutions embodying the regrets of the Society upon the departure of Mr. Haven from the State to engage in professional work elsewhere.

F. J. SMITH, *Secretary*.

Boston Society of Civil Engineers.

ANNUAL MEETING, MARCH 18, 1896.—The annual meeting of the Society was held at its rooms, 36 Bromfield Street, Boston, 7.55 P.M., President Albert F. Noyes in the chair. Ninety-nine members and visitors present.

The record of the last regular, and the special meeting of February 26th, were read and approved.

Messrs. James F. Bigelow, Arthur E. Horton, George E. Howe, Will B. Howe, Louis C. Lawton, Dana M. Pratt, Henry A. Varney, and Russell H. Whiting were elected members of the Society. Past President George L. Vose was elected an honorary member.

The amendment to By-law 10, proposed at the last meeting, so that the first two sentences shall read: "The entrance fee shall be ten dollars. The annual dues shall be *eight* dollars for members and associates residing within thirty miles of Boston, and *five* dollars for those residing at a greater distance, payable in advance at the annual meeting," was adopted, 35 in favor and none against.

The annual report of the Board of Government was read by the Secretary, and on motion it was accepted and placed on file.

The annual reports of the Secretary and the Treasurer were read by these officers, and on motion were accepted and placed on file.

Mr. Main presented the report of the Committee on Weights and Measures, and on motion it was accepted and ordered to be printed in the proceedings of the Society.

Mr. Wood read the report of the Committee on Excursions, and on motion it was accepted and placed on file.

Mr. Doane made a verbal report for the Committee on Quarters, which was accepted.

Mr. Flinn presented the report of the Committee on the Library, and on motion it was accepted and placed on file. On motion of Mr. Blodgett, the recommendations made in the report of the Committee on the Library were referred to the Board of Government, with full powers.

On motion of Mr. Stearns it was voted to refer to the Board of Government, with full powers, the question of continuing the several special committees and the selection of the members thereof.

The President read a communication from the President of the Western Society of Engineers in relation to a bill before Congress looking to the appointment of a Commission on Public Architecture. He also reported, for the Board of Government, by whom the matter had been considered, that the Board did not think it advisable for the Society as a body to take definite action in the matter. The communication was received and placed on file.

Mr. Henry A. Phillips read a paper on certain aspects of the relations between the work of the architect and the engineer. The paper was mainly devoted to a

plea for the preservation of the Bulfinch front of the Massachusetts State House. It was discussed by Messrs. L. F. Rice and E. P. Adams.

Messrs. W. B. Fuller and C. E. Putnam, the tellers appointed to canvass the letter-ballots for officers, submitted the result of their count. There being no election for Vice-President and Librarian, the meeting proceeded to choose these officers from the two candidates for each office having the highest number of letter-ballots. As the result of the letter-ballot and the choice of the meeting, the President announced the following officers elected:—

President, George F. Swain.
Vice-President (for two years), Henry D. Woods.
Secretary, S. Everett Tinkham.
Treasurer, Edward W. Howe.
Librarian, Alfred D. Flinn.
Director (for two years), Frank W. Hodgdon.

President Alfred F. Noyes then delivered his annual addresss.

ADDRESS OF PRESIDENT NOYES.

It has been the custom for the President of your Society at the annual meeting to give a general review of the progress made during the year, in the execution of engineering works, and to give a summary of the results obtained. It is not my intention to-night to refer, more than in a general way, to the engineering achievements and works now being carried on or almost completed, and to refer to the progress made in engineering in our own State, a territory which may be assumed to be the special jurisdiction of this Society; but it is my intention to speak to you more with regard to the future of the Society, and to offer suggestions as to means for increasing its usefulness, both to ourselves and to the profession at large.

The Society will, in July of this year, have been organized forty-eight years. These years have seen a wonderful growth in the usefulness of the profession, and the public have come to depend upon and place greater confidence in the advice of the engineer, not only in the preliminary consideration of all questions relating to public improvement, but in carrying them to successful completion.

Probably in no State in the Union has so much been done by the General Government as has been done by the Government of the State of Massachusetts, in the way of authorizing great engineering works, and in making possible careful investigations upon engineering questions, from the results of which information is obtained of great permanent value to the whole country. The appropriations enabling the State Board of Health to continue the investigations and experiments carried on at the Lawrence Experiment Station, to maintain a more complete supervision over, and to continue the examination of the water supplies, as well as the examinations to determine the results obtained by the operation of the various sewage disposal works in the State, have been continued, and has been even more liberal than for previous years. During the year the construction of both the North and South Metropolitan Sewerage Systems, which were begun in the year 1890, have been practically completed and put in operation. The investigation, made under the direction of the State Board of Health, with regard to obtaining an increased water supply for the Metropolitan District, has been completed; and by authority given by special act of the Legislature, the work has not only been authorized, but has been begun. It may be of interest to note that the details of the plan of the proposed system have been so carefully considered that the appropriation providing for the construction of the work was made, and measures taken

contemplating the construction of the system without one word of criticism upon the plans.

The Metropolitan Park System, which contemplated the taking of large areas of unimproved land located in the Metropolitan district, and land having great natural attractions, has been extended so that there is now assured to the public forever the preservation of these great breathing and recreation grounds for the constantly increasing population of the Metropolitan District.

The work of constructing the subway, under the direction of the Boston Transit Commission, which will provide in a measure a way by which more rapid transit can be obtained through the congested portions of the City of Boston, has been well begun.

There has been a continued demand for the construction of State roads, as proposed by the Massachusetts Highway Commission in their report of 1893, and appropriations aggregating over $700,000 have been made and expended under the direction of that Commission, and has enabled them to construct 89.91 miles of road with stone or McAdam surface, and has demonstrated to the various municipalities the benefits to be derived by the construction of these roads, as well as the economy affected, and comfort and convenience resulting from their use. This object-lesson has led to a demand for a still greater extension of the State Highway System, with requests from the authorities in all parts of the State for an appropriation this year of from one to two million dollars.

Investigations have been made and plans proposed, through a special commission, for the improvement of Boston harbor. Sewer systems have been designed, construction begun or extended in nearly if not quite all of the municipalities in the Metropolitan District.

Nearly all of the cities and some of the towns in the State have organized and maintain a department of municipal engineering, and some of the cities and towns have recognized the value of the services of the Consulting Engineer to advise upon the special work of the department, and have regularly retained the services of such an officer. Nearly all of these municipal offices have been filled and works executed by or under the direction of members of this Society ; and the members of this Society have still further been recognized as administrative officers by the appointment of at least one of its members on most of the State Commissions having anything to do with or requiring the services of the Engineer ; and so assured is the confidence of the public in the ability of the engineer that no work of any importance is undertaken without first being investigated and reported upon by him. It is but rare that any work is placed in his hands without first looking up carefully his professional experience and reputation ; and it is an encouraging sign that the question of price to be paid for his services does not, except in a few cases, actuate the client in his selection of an engineer, but that professional reputation and experience is of first importance.

Each year has seen an increase in the membership of the Society, and during the past year the increase has been larger, and the interest in the meetings, as shown by the attendance, has also been greater than during any previous year. With this increasing membership, and increasing demands upon the service of the engineer for all classes of work, there has been a natural tendency for specializing their work ; and in order that the greatest amount of benefit may be obtained by each individual member, it becomes necessary for us not only to consider but to realize that the members must be provided with the literary food which their tastes demand. The demands upon the profession have become so great that with each

succeeding year there is a greater tendency to specialize in its work, so that to-day the engineer who takes an advanced position in the profession, while he may have a general knowledge of and desire to keep informed with regard to all phases of engineering specialties, there is a tendency to devote his whole energies to one or more of the special lines where his interests will centre.

The Society has already become so large that there are sufficient numbers of representatives of almost every branch of engineering to form a nucleus for the organization of a separate society representing the interests of each branch. Already have the interests in water-works and highway construction and maintenance become so great that branch organizations have been formed which have included in their membership a large number of members of this Society. Included in the membership of these societies are the practical operating men in their special lines, and men who would not, in some respects, from their experience be eligible for membership to this Society. Attendance at the meetings of these societies bring our representatives in contact with the active men in the work they are engaged upon, and they get a benefit which would not be obtained at the meetings of this Society; hence I do not look upon these organizations as being in any way a menace to the interests of this Society.

There are, however, other branches of engineering, namely, the Mechanical, the Marine, the Railroad, the Municipal, the Electrical and the Sanitary Engineer, whose membership in the Society have become so large as to lead some to seriously consider the organization of societies or clubs dealing with questions of special interest to their branch of the profession. There does not appear to be the large field from which to draw any considerable number of persons to such societies or clubs if formed, who would not be eligible for membership to this Society; hence the organization of such societies can be considered, if withdrawing attendance and interests in this Society, as a means of decreasing its usefulness.

The question now before us, as the membership increases, and its numbers become so great as to make the body in some respects unwieldy, is how to get the greatest possible good to all working in the special lines which the profession is bound to divide itself into. As it is necessary that each specialist should be in touch with the other's works, it is, I believe, by the work of this Society, that these results can be accomplished.

The literary portion of the exercises at our monthly meetings has generally been provided by members of the Society, and has consisted of a description of work being carried on, executed, or investigations made. The papers have generally been obtained either by the voluntary offer of the members, or at the solicitation of the Secretary or President of the Society. The topics considered have usually been suggested by these officers; and from their comparatively limited knowledge of what may be going on in the various branches of the profession, it is not at all surprising that a larger amount of desirable information is not obtained. The informal library meetings, so successfully begun and continued during the past two years, have been a source of great interest and profit to the members, and this interest is increasing, so that on several occasions the meetings have been held in the small hall in the rear of this hall.

I have frequently heard criticism or complaint offered from members representing special branches of engineering in the Society, as an excuse for not taking more interest and attending the meetings; that the papers read were not of special interest to them. My answer to these critisms has invariably been that it was their place to take hold and offer to the Society the results of their best work and inves-

tigation upon these lines of special interest to them. This will have the effect of bringing out discussions, and the mere putting in shape of a paper sufficiently carefully considered to justify submitting to the Society will be of great personal benefit to the members undertaking it. It is only by organization, each doing his share, and that share is all that each is capable of doing, that the best possible results can be obtained.

In our new quarters there will be ample room for gatherings of any considerable body of the Society. I would suggest the following form for sub-organization: That committees of the Society be formed, these committees containing within their numbers the members representing the various branches in the profession, and might be called committee on Architectural, Mechanical, Sanitary, Hydraulic, Railroad, Municipal, Marine and Electrical Engineering. These divisions or committees may be made by the Board of Government, or the members may signify to the Board of Government their desire to become attached to one or more committees representing the special division or divisions of engineering work they are interested in. These committees would make up their own organization by the choice of a chairman and secretary, and it should be their duty to provide literary entertainment for both the regular and library meetings which would be assigned to them, and they to consult with each other as to in what way papers of the greatest professional value can be prepared and presented at these meetings. A spirit of rivalry among the various committees could be encouraged by the offer of a prize or special mention for papers of merit prepared by the members of each. In order that there may be a unity of action between each of the committees, a central organization, consisting of the President and Secretary of this Society and the Chairman and Secretary of each of the committees, could be effected with the President and Secretary acting respectively as chairman and secretary of the joint committee. The interest in the work of the various committees can be still further increased by special literary or social meetings held at such time as they may elect other than the time of the regular meetings of the Society, and at which they could discuss topics of special interest to their branch.

By carrying out and developing the plan substantially as outlined, each member would be able to keep in touch with all branches of engineering work, which his special calling would not ordinarily permit, except from availing himself of advantages to be obtained by these meetings. Each would feel that he had a work to do, which can hardly be the case under the existing conditions of organization. I believe the carrying out of such a plan would bring to the Society the membership of many men interested in special lines of professional work, and result in the production of papers of greater professional value.

I understand that, in past years, a plan, somewhat similar to that outlined above, has been made part of the organization of the Engineers' Club of Philadelphia, by which special committees have been appointed, whose duty it was to provide literary entertainment for each meeting night during the year, the work of the year being laid out as soon as practicable after the annual meeting. I further understand, it was an unwritten obligation on the part of the members of that Society that these papers be prepared, and the execution of the plan has resulted in the preparation of papers of unusual professional value.

While dwelling upon the question of methods for increasing our usefulness, I cannot forbear to speak a word to the older members of the Society, and when thus speaking it must be borne in mind that each one who is older than the youngest may be included in this class.

Several of the guests at the annual dinner of the Society remarked as to the large number of young men there were present, and it could not but lead me to reflect that a considerable majority of the members of the Society were comparatively young men working in their own field, but striving to reach a higher position in that field, and to increase their usefulness. I have been frequently asked by the younger men, as I presume most of the older men of the profession have been asked, as to what course to pursue and the best way to prepare themselves to make more advanced standing in their work. At these times I can but recall the period when I have asked myself this question; and, in fact, the question is constantly recurring to me as I look about and see older persons in the profession than myself, and those who by application and persistent work have reached more advanced positions, I feel an inclination to ask the same question of them; and I am led to ask you to-night, fellow-members, are we doing all we can in our personal work to assist the younger members, both of the Society and the profession, and are we doing our full work, and work which will enable them to more quickly take the advanced standing in the profession which is sure to result in a benefit to us all?

These thoughts and suggestions I have only been able to present to you in a rough and undeveloped state, feeling that they are worthy of your future consideration, that by general discussion, which I would gladly invite, that which may be good in them may be culled out and result in the general good to all.

In closing I wish to thank the members of the Board of Government and the members of the Society for their cordial co-operation and assistance to me as their presiding officer. This co-operation and assistance has made the work of the year both easy and pleasant; and I can assure you I deeply appreciate the honor which has been conferred upon me by being selected to serve in the capacity of President during the past year, and I can safely predict that with each year there will be an ever increasing amount of good accomplished by the united work of the members of this Society.

At the close of the President's address the Society adjourned.

S. E. TINKHAM, *Secretary.*

ABSTRACT OF ANNUAL REPORT OF BOARD OF GOVERNMENT FOR THE YEAR 1895-96.

Ten regular meetings and one special meeting have been held during the year and the fourteenth annual dinner of the Society was given on March 3, 1896. The average attendance at the regular and special meetings was 87, the smallest being 60 and the largest 142. The number present at the annual dinner was 170.

At the last annual meeting the total membership of the Society was 354, of which 348 were members, 4 honorary members and 2 associates.

During the past year we have lost 15 members: 5 by death, 4 by resignation, 1 by transfer to the Engineers' Club of St. Louis, and 5 by forfeiture for non-payment of dues.

There have been added to the Society during the year 50 members: 49 by election, and 1 who had resigned membership was reinstated. The net increase in membership has been therefore 35.

The present membership of the Society consists of 4 honorary members, 4 associates, and 381 members; a total of 389.

The records of deaths for the year is as follows:

John H. Webster, died April 2, 1895; Adelbert L. Sprague, died April 12, 1895; Marshall M. Tidd, died August 25, 1895; Willis H. Hall, died August 26, 1895; Horace L. Eaton, died November 23, 1895.

Negotiations have been had with the Committee of the Tremont Temple Baptist Church Corporation with a view of obtaining quarters in the new Tremont Temple Building, where not only the library, which is now owned by the Society, can be arranged so that it will be readily accessible for the use of the members, but where space can be had for increasing the library and making it an element of use and profit. This has resulted in a lease being taken of quarters on the seventh floor of the building for a period of three years, with the privilege of renewing said lease for three years more. The new quarters consist of one large room about 18 by 43 feet, of sufficient size to provide room for the proper arrangement of the present library, and for such additional books as will probably be obtainable for a period of several years. Arrangements have also been made for the joint use of the room with the New England Water Works Association, an association which has, to a considerable extent, kindred interests and work to that of our Society, and to which society a very large number of the members of this Society belong.

Adjoining the new room of the Society, on the floor below, is a large hall of ample size to accommodate the probable attendance to most of the meetings of the Society for several years to come. A popular subscription has been made for furnishing the rooms of the Society, and the amount of the subscription is about $712.00. It is hoped that this amount will be increased to about $1,000, which it is hoped will furnish a small sum to provide for the proper arrangement of the library and the cataloguing of the books.

ABSTRACT OF THE TREASURER'S AND THE SECRETARY'S REPORTS FOR THE FINANCIAL YEAR 1895–96.

CURRENT FUND.

Receipts.

Balance on hand March 20, 1895	$156 94
Received from dues of members	2,363 00
Received from rent of office to March 15, 1896	150 00
Received from sale of Journal	6 50
	$2,676 44

Expenditures.

Association of Engineering Societies	$1,356 31
Rent	500 00
Printing, postage and incidentals	345 47
Secretary's salary	200 00
Incidental expenses of annual dinner of 1895	72 90
Periodicals and binding	24 25
Expenses at meetings, stenographer and lantern	80 75
Cash on hand	96 76
	$2,676 44

PERMANENT FUND.

Receipts.

Balance on hand, March 20, 1895	$1,190 39
Forty-eight entrance fees	480 00
Payment of real estate mortgage	1,000 00
Shares of Merchants' Co-operative Bank, retired . .	428 72
Interest and dividends	127 29
	$3,226 40

Expenditures.

New shares in Merchants' Co-operative Bank	$351 84
Dues on shares in Co-operative Banks	775 00
Cash on hand, uninvested	2,099 56
	$3,226 40

SCHEDULE OF FUNDS OF THE SOCIETY, MARCH 18, 1896.

1 Republican Valley Railroad bond (par value) . .	$600 00
9 shares, C., B. & Q. R. R. stock (par value)	900 00
Shares in Co-operative Banks	3,040 65
Cash on hand, permanent fund	2,099 56
" " current fund	96 76
" " fund for furnishing new rooms	300 00
	7,036 97
Schedule presented at last annual meeting	6,022 50
	$1,014 47

REPORT OF THE COMMITTEE ON WEIGHTS AND MEASURES.

BOSTON, MARCH 18, 1896.

To the Boston Society of Civil Engineers:

GENTLEMEN:—The only definite and tangible thing which has taken place during the past year through the Committee on Weights and Measures is the passage, after much trial and tribulation, of the resolution:—

Resolved, That the Boston Society of Civil Engineers earnestly deprecate the use of any of the wire and sheet metal, or other trade guages now in vogue, and strongly urge the use of a *decimal system* for all such measurements.

A resolution similar to this has been adopted by several of the engineering societies in this country.

During the past year the Metric System of weights and measures has been made obligatory and exclusive by the Turkish Government.

The Bulgarian Government has issued a notification to the masters of ships bound to Bulgarian ports that, unless their cargoes are weighed in kilograms, they must be reweighed at the expense of the shipper.

According to the New York *Evening Post*, the United States, England and Russia are the only civilized countries not using the Metric System.

There is a bill before Congress, introduced December 26, 1895, which has been read twice and referred to the Committee on Coinage, Weights, and Measures, on which hearings have commenced before the Committee.

The Bill is as follows:—

A BILL

to fix the standard of weights and measures by the adoption of the metric system of weights and measures.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That from and after the first day of July, eighteen hundred and ninety-seven, all the Departments of the Government of the United States, in transaction of all business requiring the use of weight and measurement, shall employ and use only the weights and measures of the metric system, as legalized by Act of Congress approved July twenty-eighth, eighteen hundred and sixty-six.

Sec. 2. That from and after the first day of July, eighteen hundred and ninety-nine, the metric system of weights and measures shall be the only legal system of weights and measures recognized in the United States.

Sec. 3. That the tables in the schedules annexed to the bill authorizing the use of the metric system of weights and measures, passed July twenty-eighth eighteen hundred and sixty-six, shall be the tables of equivalents which may be lawfully used for computing, determining, and expressing in customary weights and measures the weights and measures of the metric system.

February 13, 1895, a Select Committee was appointed by the House of Commons to inquire whether any and what changes in the present system of weights and measures should be adopted.

July 1, 1895, the Committee made their report to the House of Commons, the summary of which is as follows :—

Your Committee recommend :

(*a*) That the metrical system of weights and measures be at once legalized for all purposes.

(*b*) That after a lapse of two years the metrical system be rendered compulsory by Act of Parliament.

(*c*) That the metrical system of weights and measures be taught in all public elementary schools as a necessary and integral part of arithmetic, and that decimals be introduced at an earlier period of the school curriculm than is the case at present.

These and other signs show that slowly, but surely, the metric system is advancing and that its use is gradually increasing.

In the issue of January 17, 1896, of that conservative paper, *London Engineering*, appeared an editorial on "The Metric System and Standard Screw Threads." We will quote a portion of this article :

"We regard it as an absolutely foregone conclusion that the metric system will be adopted here, and the only points open to discussion are how the transition can be made most easily," etc., . . . "but those that can read the signs of the time, now see its advancing shadow. Pushing firms, like Messrs. Williams & Robinson, have adopted it voluntarily, conscious of the immense advantage it gives them in the export trade, and others are casting about for the means to follow their example."

Engineering Record of March 7, 1896, states that the Engineering Association of the South has instructed its Secretary to write to the Tennessee members of Congress, urging them to vote in favor of the Metric reform.

The change which is proposed in the bill before Congress must be of great interest to the Boston Society. Judging from the action of the Society on the

resolution relating to Wire Gauges, your Committee feel that the Society would probably not care to take any action as a body, but if any members show a desire to obtain individual expressions of opinion of the members, the Committee will proceed to obtain these expressions as far as possible, for and against the proposed measure, in the form of signatures to petitions for and against the passage of the bill.

CHAS. T. MAIN,
ALLEN HAZEN, } *Committee.*
DWIGHT PORTER,

REGULAR MEETING, APRIL 15, 1896.—A regular meeting of the Society was held at its rooms, 36 Bromfield Street, Boston, at 7.50 P.M. Sixty-eight members and visitors present.

President George F. Swain, on assuming the chair, thanked the members for the honor they had conferred upon him in electing him to preside over the Society for the coming year.

The record of the last meeting was read and approved.

Messrs. Joshua Atwood, 3d, Maturin H. Ballou, Sidney K. Clapp, William C. Cuntz, John N. Ferguson, Fred G. Floyd, Henry K. Rowell, William J. C. Semple, and Fenwick F. Skinner were elected members of the Society.

The President announced the deaths of the following members of the Society:—William A. Allen, who died March 21, 1896, and Waterman Stone, who died March 30, 1896.

On motion, the President was requested to appoint committees to prepare memoirs. The Committees appointed consist of Messrs. E. W. Howe and H. Bissell to prepare the memoir of Mr. Allen, and Messrs. J. W. Ellis and E. B. Weston that of Mr. Stone.

On motion of Mr. Fuller the thanks of the Society were voted to the Quincy Market Cold Storage Co., and to Mr. Geo. H. Stoddard, its manager, for courtesies shown to members taking part in the excursion to its warehouses this afternoon.

The Secretary reported for the Board of Government that it had appointed the following special committees:—

On Weights and Measures, Charles T. Main, Allen Hazen and Dwight Porter.

On Excursions, E. S. Dorr, F. O. Whitney, W. E. McKay, E. S. Davis and Morris Knowles.

On the Library, A. D. Flinn, S. E. Tinkham, H. F. Bryant, M. S. Pope and W. B. Fuller.

On Quarters, Thomas Doane, Desmond FitzGerald, E. W. Howe, C. F. Allen and E. W. Bowditch.

Members of the Board of Managers, S. E. Tinkham, J. R. Freeman, Henry Manley and Frederick Brooks.

A letter was read from Prof. George L. Vose, accepting his election as an honorary member and expressing his thanks for the same.

The Librarian brought to the attention of the Society the desirability of reserving for the use of the library, a portion of the fund subscribed for furnishing the new rooms. After some discussion it was voted, that the custodian of the fund for furnishing the rooms be requested to reserve $100 of that fund for the procuring of a card catalogue of the library.

Mr. Joseph R. Worcester was then introduced, and read a very carefully prepared paper on Riveted Joints.

The paper was discussed by Mr. James E. Howard, Engineer of Tests at the Watertown Arsenal, and by Messrs. Lanza, Cheney, Hollis, Snow and Guppy of the Society. The Secretary also read discussions prepared by Messrs. E. S. Shaw and J. C. Moses.

Adjourned.

S. E. Tinkham, *Secretary.*


ASSOCIATION OF ENGINEERING SOCIETIES
Longitude 105 West from 90 Greenwich
MONTANA
MINNEAPOLIS
ST. PAUL
DENVER
KANSAS CITY
ST. LOUIS
CLEVELAND
BOSTON
Philadelphia
VIRGINIA
PACIFIC COAST
GULF OF MEXICO
Bradley & Poates, Engr's, N.Y.

Association of Engineering Societies.

Vol. XVI. | May, 1896. | No. 5.

PROCEEDINGS.

Engineers' Club of Minneapolis.

Minneapolis, Minn., April 20, 1896.—The regular meeting of the Engineers' Club of Minneapolis was held at the office of the City Engineer, City Hall, at 8 o'clock p.m. The President, F. W. Cappelen, in the chair.

Communications in reply to letters relative to House Bill No. 1470 were read from Geo. F. White, M.C., "that he was in favor of adding Engineers to the Commission of Public Architecture;" from Lorin Fletcher, M.C., "that he would do everything he could to the same end;" from Knute Nelson, that "he would call the attention of the Committee on Public Buildings and Grounds, in the Senate, to the matter."

A communication from the Chicago *Journal of Commerce and Metal Industries*, stating they had placed our Club on the complimentary list. On motion the thanks of the Club were extended to them.

The menu of the 16th annual banquet of the Civil Engineers' Club of Cleveland, O., sent our President, was read and appreciated.

F. H. Constant was unanimously elected a member of the Club.

The committee appointed to investigate the matter of quarters for the Club in the New Court House and the Public Library, reported that there were no vacant rooms in either building.

On motion a new Committee on Quarters, consisting of F. W. Cappelen and G. C. Andrews, was appointed.

The names of Chas. E. Pillsbury and C. H. Kendall were proposed for membership by A. B. Coe and W. R. Hoag.

Mr. Loe sent word he had been unable to complete for this meeting his paper on Flour Mill Construction.

Mr. A. B. Coe read a paper on Measurement of Difficult Base-line, which was informally discussed.

Mr. F. W. Cappelen promised a paper on Electric Lighting.

On motion adjourned.

Elbert Nexsen, *Secretary.*

Technical Society of the Pacific Coast.

Regular Meeting, May 1, 1896.—Called to order at 8.30 p.m., by Vice-President Curtis.

The minutes of the last regular meeting were read and approved.

S. D. Schindler, Civil Engineer, of San Francisco, applied for membership; proposed by A. I. Frye, D. C. Henny and Randell Hunt.

The Secretary proposed the following, which was unanimously adopted:

Whereas, It has been made known to the Technical Society that the American Society of Civil Engineers would hold its annual meeting in the city of San Francisco, on or about the 28th of June, 1896, therefore, be it

Resolved, That this Society tender to the American Society the use of its rooms during its stay in our city; that we invite all visiting members to make their business headquarters with us, and to partake of the hospitalities of the Technical Society of the Pacific Coast, which are hereby cheerfully and heartily extended to all those who may visit California on this occasion.

A copy of this resolution was submitted to Vice-President Curtis, to be forwarded to the committees of the American Society of Civil Engineers.

The following communication was read:—

"It is the sad duty of this Society to chronicle the death of a man who, until within a short time of his demise, had been a prominent and active member of the Technical Society. It is suggestive and proper that reference be made to the life and history of Chas. A. Stetefeldt, who was well known to almost every member of the Society, and whose genial ways and kindly nature had endeared him to the hearts of all those with whom he came in contact. He died in Oakland, California, on the morning of March 17th, at the age of 57 years, after an illness of short duration. His death was entirely unexpected, and was to all of his acquaintances a source of heartfelt grief."

The following notes have been taken from a memoir written by an old colleague of the deceased, Mr. R. W. Raymond, who gave it publication in the *Engineering and Mining Journal*, of March 28, 1896:—

"Chas. A. Stetefeldt was born September 28, 1838, at Holzhausen, a village in Thuringia, Germany. He was educated at home by his father, a Lutheran minister, until, at the age of 14, he was sent to the Gymnasium at Gotha. While there he was one of the founders of the "Naturwissenschaftliche Verein der Gymnasiasten zu Gotha," a society which still exists and flourishes.

"In 1858 he entered the university at Goettingen, where he remained for two years, studying principally under Woehler, Wilhelm Weber, Sartorius von Walters hausen and Stern. He then went to the School of Mines at Clausthal, and passed there, in 1862, the 'Ingenieur-Examen,' receiving the first degrees in all branches. The following year he spent in the principal metallurgical works in Germany, especially at Freiburg, and emigrated in 1863 to the United States.

"A few days after his arrival in New York he was engaged as assistant by Charles Jay, Professor of Chemistry at Columbia College. It was in the following year that he became an assistant in the office of R. W. Raymond.

"He possessed a knowledge of mathematics and chemistry much beyond the usual equipment of a mining engineer or metallurgist, and, at the same time, an exceptionally wide scientific and literary as well as technical culture.

"In 1865 he established, with John H. Boalt (then a mining engineer, pure and simple) a branch office at Austin, Nev., in the then 'booming' Reese River district.

Soon after coming to America, he had taken out a patent for a special arrangement of the Gerstenhofer shelf-furnace for desulphurizing pyritic ores, but, after a single unsatisfactory trial in Colorado, the invention was practically abandoned.

"But out of his adverse experience the skill and genius of Stetefeldt extracted a conception of real and permanent value. Having satisfied himself that, especially in an atmosphere containing chlorine, as well as oxygen, the reactions of oxidation and chlorination were so rapid as to be (for particles sufficiently small, and sufficiently exposed to this atmosphere) practically instantaneous, he boldly discarded the shelves of the Gerstenhofer furnace, substituting the free fall of the charge in an open shaft. This invention, known throughout the world as the Stetefeldt furnace, was undoubtedly both a novelty and an improvement, though the precise limits of its advantageous use are still a matter of controversy. Whatever may be the ultimate result of the discussion, the name of Stetefeldt, in connection with this furnace, will remain indelibly imprinted upon the history of metallurgy.

"After the successful introduction of this furnace Mr. Stetefeldt went to Europe, in 1870, and did not return until 1872, when he made his headquarters at San Francisco. In 1882 he returned to New York, but took up his residence again in California in 1889.

"The latter years of Mr. Stetefeldt's life were largely devoted to perfecting the construction and operation of his furnace, and in operations in metallurgical practice, to which it was auxiliary. The most important of these was the Russell process of lixiviation, concerning which he published several papers and a text-book, the second edition of which appeared last year.

"One of his latest enterprises in connection with the improvement of silver mills was the introduction of producer gas for firing dry kilns and roasting furnace at the Marsac Mill, Park City, Utah, a new departure which promises to be of great importance, and will, no doubt, be generally adopted where wood can be profitably replaced by coal."

The following resolution was offered by C. E. Grunsky :—

Whereas, This Society believes John Hayes Hammond, who is one of its members, and who has been one of its executive officers, incapable of committing any offense against any Government, deserving death penalty, and will ever believe that his actions have been prompted by honorable motives, therefore, be it

Resolved, That a committee of three be appointed to take such action, from time to time, as may seem appropriate to mitigate the severity of the sentence imposed by the authorities of the Transvaal for his connection with the reform movement in that country.

The following committee was appointed, after passing the resolution unanimously: Messrs. C. E. Grunsky, Prof. Frank Soulé and Otto von Geldern.

The following letter was read :—

April 30th.

The Secretary of the Technical Society,
San Francisco, Cal.

SIR:—Allow me, through you, to call the attention of the Technical Society to Lord Kelvin's Jubilee, which is intended to be celebrated in Glasgow on the 15th and 16th of June next. This Society should appoint a committee to confer with the Astronomical Society and the Academy of Sciences, so as to have a reunion of scientists on that occasion and do honor to one of the greatest scientific authorities of this or any other age. It would be superfluous for me to refer to the life work of such a man whose name is so well known the world over.

This completes his fiftieth year as Professor of Natural Philosophy in Glasgow University, and as about all the recompense which a great philosopher receives is honor, I think we should show our gratitude for his great services to science by at least joining the rest of the world in our congratulations to him.

With respects, yours faithfully,

[Signed] ROBERT STEVENSON.

The letter was ordered to be received, and the Secretary instructed to consult with other societies and to co-operate with them in any event to honor the fiftieth anniversary of Lord Kelvin's professional career.

A discussion was opened on the present capacity and design of steel rail used in modern railway construction, in which Vice-President Curtis favored the meeting by stating his personal experiences and results in this line of railway engineering. This interesting discussion formed the topic of the evening, after which the meeting adjourned. OTTO VON GELDERN, *Secretary.*

Civil Engineers' Society of St. Paul.

ST. PAUL, MINN., MAY 4, 1896.—A regular meeting of the Civil Engineers' Society of St. Paul was held at 8.30 P.M.

Present, thirteen members and six visitors.

Mr. W. L. Darling in the chair.

The reading of minutes was dispensed with.

Papers in the matter of a Bill to establish Experimental Engineering Stations were referred to the government of the Society.

Mr. William de la Barre, of Minneapolis, read a paper on Recent Improvements of the Water Power at St. Anthony Falls, and was accorded a vote of thanks.

C. L. ANNAN, *Secretary.*

Engineers' Club of St. Louis.

436th MEETING, May 6, 1896.—The club was called to order at 8.40 P.M., 1600 Lucas Place, by President Ockerson. Twenty-one members and two visitors present.

The minutes of the 435th meeting were read and approved. The Executive Committee reported the doings of its 214th meeting, recommending the applications for membership of E. R. Fish and H. C. Meinholtz. They were balloted for and elected. The committee reported having extended the privileges of the club rooms to the visitors to the Convention of the American Gas Light Association, to be held in this city three days, beginning October 21st next.

The committee recommended that the invitation of Mr. E. C. Parker to visit Cupples Station be accepted, and the date fixed for the afternoon of Friday, 22d inst. On motion so ordered.

The committee reported the proposed agreement with the Electric Club for the care of its library without recommendation. On motion ordered that their proposition be accepted, and contract executed. On motion, the Executive Committee was directed to have all the books under the care of this club insured.

The Special Committee on Convention of the American Society of Mechanical Engineers recommended that the club appropriate $150 from its treasury to the

Entertainment Fund. On motion so ordered. On motion ordered also that the secretary extend to the Convention the privileges of the library during their coming Convention.

On motion ordered that the thanks of the club be extended to Messrs. Robert Moore and R. E. McMath for valuable donations to the library.

The secretary read a letter from John C. Trautwine, Jr., asking the club's consideration of a bill now before Congress to establish engineering experimental stations. On motion ordered that the matter be referred to Prof. J. B. Johnson for investigation and report.

By request, Prof. Johnson then read an abstract of Mr. J. W. Woermann's paper on "The Construction of a Low Crib Dam Across Rock River." The paper was illustrated by numerous photos and blue prints. This dam is one of the structures of the Illinois and Mississippi Canal, known as the "Hennepin Canal," and is intended to furnish slack water navigation in Rock River above the lower rapids. The exact location, design, methods of construction, foundations, material used and the cost of the work, were fully given, together with a statement of the force employed and the time required to do the work.

Prof. J. H. Kinealy then described a form of planimeter which could be made of a single piece of wire, showing the methods of operating it, and principles upon which it was based. Under certain limited conditions of service, and if used with great skill, quite accurate results were possible. After considerable investigation and study Prof. Kinealy had worked out the mathematical theory of the instrument.

The discussion was participated in by Messrs. Harrington, Dunaway, Ockerson, Baier and Freeman.

The president announced that there would be no meeting on 20th inst., as the American Society of Mechanical Engineers would then be in session. Adjourned.

William H. Bryan, *Secretary.*

Montana Society of Civil Engineers.

The regular monthly meeting of the Montana Society of Civil Engineers was held Saturday evening, May 9, 1896. The meeting was called to order by President John Herron. There were present C. W. Goodale, F. J. Taylor, Finlay McRae, A. S. Hovey and F. J. Smith.

The minutes of the previous meeting were read and approved.

Messrs. Taylor and McRae were appointed tellers to canvass the ballots for admission to membership. The result of the count being announced, the president declared that Mr. Abram L. Jaqueth had been elected a member of the society.

Senate Bill No. 2301, which provides for the establishment of engineering experiment stations, after being read and discussed, was, on motion, referred to Prof. A. M. Ryon, who, as a committee of one, was directed to investigate the merits of the Bill and to report at the June meeting.

It was voted that a committee of three be appointed "To look after legislative nominations." Messrs. McRae, Goodale, and McNeill were selected as members of this committee.

Mr. Finlay McRae was elected trustee, by acclamation, to fill the vacancy caused by the resignation of Mr. W. A Haven.

Adjourned.

Forrest J. Smith, *Secretary.*

The Civil Engineers' Club of Cleveland.

MEETING, held May 12, 1896.—President Howe in the chair. Present 60 members and visitors. The minutes of the last meeting were read and approved. Messrs. Paul and Brown were appointed tellers to canvass the ballots for new members. Mr. Searles reported progress for the Committee on Association of Cleveland Scientific Societies.

The paper of the evening was then read by Mr. E. A. Sperry. It was entitled "Steam Engines for Direct-connected Electric Generators," and described his invention by means of which the Generator makes two revolutions at each stroke of the engine.

The discussion which followed was participated in by Messrs. Newman, Herman, Cowles, McGeorge, Dodd, Warner, and others.

Mr. Mergatroid presented some interesting facts in regard to the development of Rotary Engines and Steam Turbines.

The President announced the receipt of two more papers for the year's program: by Dr. D. C. Miller, May 26th, on "Phenomena of Electrical Discharges in Vacuo," illustrated by apparatus; and by Mr. W. R. Warner, October 13th, on "Modern Construction of Scientific Instruments."

The President then announced the election to active membership of Messrs. R. L. Newman, S. W. Hayes, A. M. Waitt, C. O. Arey, and W. B. Cowles; and the election to associate membership of Messrs. W. J. Walker, S. B. Sheldon, H. P. Fairfield, and Wm. Secher.

The Club then adjourned, and the members repaired to the neighboring restaurant where a lunch awaited them.

F. A. COBURN, *Secretary.*

MEETING OF THE CIVIL ENGINEERS' CLUB, Club Rooms, May 26, 1896.—Vice-President James Ritchie in the chair. Present 85 members and visitors, including many ladies.

Reading of the minutes of the previous meeting was dispensed with. Dr. D. C. Miller read a paper on "Phenomena of Electrical Discharges in Vacuo," describing and experimentally illustrating the researches of Geissler, Hittorf, Crookes and Roentgen. The discovery of the X-rays was demonstrated, and the various theories proposed to account for the phenomena briefly explained.

The practical applications of the X-rays were explained with the aid of the fluoroscope and lantern projections.

After the meeting the company availed themselves of the opportunity, by the aid of the fluoroscope, of seeing the bones of their hands and wrists.

A light lunch was served.

F. A. COBURN, *Secretary.*

Association of Engineering Societies.

Vol. XVI. | JUNE, 1896. | No. 6.

PROCEEDINGS.

Boston Society of Civil Engineers.

Regular Meeting, May 20, 1896.—A regular meeting of the Society was held in Chipman Hall, Tremont Temple, Boston, at 8.15 o'clock, p.m., President George F. Swain in the chair. Number of members and visitors present, including ladies, 318.

The record of the last meeting was read and approved.

Messrs. Bertram Brewer, Emory A. Ellsworth, Charles F. Fitz, Jr., Edward I. Marvell, Lester W. Tucker, Frederic A. Wallace and William Wheeler, were elected members of the Society.

Mr. Fred Vincent Fuller was then introduced and gave a very interesting description of a recent trip to Mexico under the title of "One Month in Aztec Land." The paper was fully illustrated by lantern slides.

Adjourned. S. E. Tinkham, *Secretary.*

Engineers' Club of St. Louis.

437th Meeting, June 3, 1896.—President Ockerson called the Club to order at 8.35 p.m., at 1600 Lucas Place, eighteen members and four visitors present. The minutes of the 436th meeting were read and approved. The committee to whom was referred the bill to establish engineering experimental stations throughout the United States, reported as follows :

"*Engineers' Club of St. Louis:*

"Gentlemen :—The attached bill provides for giving to each State and Territory $10,000 a year, this sum to be increased by $1,000 annually for fifteen years, until the sum amounts to $25,000 a year for each State and Territory, and to remain at this figure thereafter, for the purpose of providing for engineering experiments in these several States and Territories. In other words, upwards of $1,250,000 annually is to be donated by the general government for engineering experimentation in about fifty different laboratories, most of which are now, and would remain, in relatively incompetent hands.

"There is now expended for experimental work on the strength of materials, at the Watertown Arsenal, the sum of $10,000 per annum, and this small amount has

proved sufficient for many years to maintain that work on a high plane of accuracy and efficiency. It seems hardly possible that the proposed large sum could be profitably spent in fifty different educational institutions, with anything like an adequate return to the cause of scientific experimentation. If engineering experiments are carried out by inexperienced and incompetent persons, and the results published by the general government, as is here proposed, these results are likely to be more or less erroneous and misleading, and might prove to be of more injury than benefit in engineering practice.

"In the opinion of the undersigned, this bill is an example of many that are now urged upon Congress which are consistent only with a more highly paternal form of government than ours has yet become.

"It is recommended, therefore, that no action be taken on this bill by the Engineers' Club of St. Louis. Respectfully submitted,

"J. B. Johnson, *Committee*."

On motion, ordered that the report be received and adopted.

The Secretary then read the following letter from the Secretary of the American Society of Mechanical Engineers:

"*Engineers' Club of St. Louis:*

"Gentlemen:—The American Society of Mechanical Engineers, at a session held just previous to the adjournment of its most successful St. Louis Convention, passed unanimously the following resolution:

"*Resolved*, That the hearty thanks of the Society be tendered to the Engineers' Club of St. Louis, and especially to its honored President, Mr. J. A. Ockerson, for the courtesies extended to the Society in the tender of the use of its comfortable house and valuable library during our stay in the city.

"You will permit me to add a personal expression of the indebtedness of the Society to the Club for attentions which it is not possible to recognize in formal and public resolution. Be assured, however, that because of the very nature of this co-operation, which had so much to do in making our meeting a pleasant memory, that I venture to add a word of personal recognition to the Club and its members individually. Very truly,

"F. R. Hutton, *Secretary*."

On motion, it was ordered that the Secretary extend the thanks of the Club to the Cupples Real Estate Company, Capt. Robert McCulloch, and the Anheuser-Busch Brewing Association, for entertainments and courtesies extended on the afternoon of Friday, May 22d.

Mr. F. B. Maltby then read a paper on "Methods and Results of Stadia Surveying," treating the subject from the standpoint of a wide practical experience. He went into the details of the work at some length regarding the appliances necessary, force required, necessity of sketching, speed with which such work could be conducted, and the cost of same, showing some charts from actual service. Mr. J. L. Van Ornum contributed a written discussion which was read by Mr. E. J. Jolley. Messrs. Colby, Thomas, Turner, Jolley, Ockerson and Russell also took part in the discussion.

Mr. Julius Baier showed the Club a number of photographs showing the damage done by the recent tornado, and discussed it from an engineering standpoint. An informal discussion followed, participated in by nearly all present, after which the meeting adjourned.

William H. Bryan, *Secretary*.

438th Meeting, June 17, 1896.—President Ockerson called the Club to order at 8.35 p.m., at 1600 Lucas Place; twelve members and four visitors present. The minutes of the 437th meeting were read and approved. The Executive Committee reported the doings of its 215th and 216th meetings.

Mr. F. F. Harrington, of the City Testing Department, then read a paper on "Experiments on Vitrified Paving Brick." He called attention to the great variations

both in the methods of testing such brick, and in the specifications for same. A committee to look into this subject had recently been appointed by the National Brick Makers' Association, and as a number of engineers were on this committee, it was thought that their recommendations would be very generally adopted. Their investigation would cover the abrasion, absorption, specific gravity, crushing and transverse strengths, and hardness. The St. Louis Testing Department had recently made a series of investigations, with a view of determining the best apparatus and methods for conducting such tests. Special study had been given to the abrasion test by tumbler, to determine the percentage of volume which should be filled, the length of the tumbler, its speed, and the duration of the test. The speaker recommended that the tumbler be filled with brick to 15 per cent. of its volume, be run at the rate of 30 revolutions per minute, and that the duration of each test be 40 minutes. He did not approve of the use of cast-iron blocks with the bricks, preferring standard or unit bricks of known character and uniformity. The drying and absorption tests were also considered.

Messrs. Holman, Freeman, Flad, Kinealy, Wheeler, Crosby and Barth took part in the discussion. Mr. Holman explained a testing machine which he had just designed for the department. Adjourned.

William H. Bryan, *Secretary.*

Technical Society of the Pacific Coast.

Regular Meeting, June 5, 1896.—Called to order at 8.30 p.m., by President Dickie.

The minutes of the last regular meeting were read and approved.

Mr. A. D. Schindler, Civil Engineer, was elected to membership.

Upon motion that a Committee be appointed to represent the Technical Society during the stay of the American Society of Civil Engineers in San Francisco, the President, Mr. Geo. W. Dickie, and two Past Presidents, John Richards and C. E. Grunsky were chosen by unanimous vote.

President Geo. W. Dickie thereupon addressed the members present on a subject entitled: "Japan as seen through the eyes of a Mechanical Engineer," being an interesting narrative of observations made during the author's recent trip to that country.

The topic was freely discussed by a number of members present, Mr. John Richards making it the subject of a very intelligent argument on the economic questions involved in the development of Japan, as influencing the industrial condition of the United States.

The meeting adjourned until August 7th, the July meeting having been stricken from the yearly list by order of the Board.

Otto von Geldern, *Secretary.*

ADDRESS BY JOHN RICHARDS,

Before the Scientific Societies of San Francisco, in the Academy of Sciences, in honor of the Fiftieth Anniversary of Lord Kelvin's Professorship, June 8, 1896.

I have been assigned the honor of presenting some remarks upon the influence and contributions of Lord Kelvin in the field of thermo-dynamics.

A first inference was that such remarks should consist in a collection of history and facts in respect to Lord Kelvin's discoveries and explanations in dynamic science, but second thought showed that such a course would be tedious, both to prepare and to hear, also would be unnecessary.

There is nothing to be proved. The position Lord Kelvin holds at this time as an authority in the field of thermo-dynamics or the interrelation of heat, motion, force, and their resulting phenomena, is an accomplished fact, known and recognized in all civilized countries, and we may say by all men.

In this country, where he was selected as the chief of a commission to determine a scheme for the great power plant at Niagara Falls, his standing in the field of applied, and even constructive mechanics, is popularly known from that fact, while our technical journals for twenty years past have accorded him a measure of respect and admiration never before bestowed upon any one occupying a place in the field of useful learning.

The present, and hundreds of other meetings of the kind, held without respect to country, race, or distance, to commemorate Lord Kelvin's fiftieth year of continuous labor in one place and one direction and interest, is perhaps the most notable evidence that can be referred to of the present position of the natural and applied sciences, and the importance now attached to studies once thought immaterial.

The assertion of such sentiment is fitting and deserved in respect to Lord Kelvin, also is happily in contrast with national dissension and jealousy, now rife in some other fields of human interest.

The reasons for this tribute are found in several facts pertaining to the assiduous and unselfish labors of Lord Kelvin.

He is not eminent because of specific discoveries in physical science, or brilliant innovations of any kind. He is, as before said, rather an "explainer" and "harmonizer" of the diversified phenomena that rise so rapidly in our day as to drive other men into narrow channels, engrossing their powers in a single branch or subject. After fifty years, marked by a prodigious development in all the arts and sciences—a period inconceivable at the beginning and scarcely to be realized at its end—Lord Kelvin has become a mentor among men, occupying a position in physical research that Humboldt did in natural science.

This breadth of opportunity, while it permitted the play of genius, imposed a herculean task by its extent and diversified nature. Thirty years may be said to cover the history of thermo-dynamics as a computable branch of applied science. Previous to that time we proceeded by experiment and empirical rules, not wholly, but mainly; and the transition to the present state of this branch, beginning when Lord Kelvin was forty-three years old, must have since then occupied no small share of his efforts.

It is not easy to trace the course of physical research from the laboratory to the workshop. Such course is commonly devious and obscure. The original concept and its laborious evolution is lost sight of. Long before it reaches the machine or process that connects it with useful industry, the original work has disappeared or is regarded as of no importance.

It would be easy to supply striking illustrations of this fact and thus connect the name of Lord Kelvin with motive apparatus, manufacturers, transportation and other of the great agencies that make up the present industrial systems of the world, but, as remarked at the beginning, this is not called for on the present occasion, or before an audience like this, the purposes being, as I understand it, to offer

a tribute of respect to a man who has won a high position, universally conceded, and not requiring proofs at our hands.

For thirty years past his name has been directly or indirectly connected with almost every advance, and we must remember that long ago there was not even common acceptance or knowledge of the conservation of energy, or the correlation of forces, and that what now is common means at the hands of the engineer and mechanic, was then not existing, or locked up in treatises inaccessible except to the learned.

To the genius of Lord Kelvin is added a charming personality, combative in a high degree, but evincing only earnestness and sincerity, with due deference and respect for the opinions of others. His course in scientific research illustrates in that field, what his countryman, Thomas Carlyle, achieved in ethics.

There is indeed analogy between the two men in some respects; but William Thomson had to deal with stubborn facts and figures that would prove themselves, while Thomas Carlyle enjoyed the license of imagination and could mix up with his philosophy, opinions that did not require to be expressed in equation.

It will be no disparagement of Lord Kelvin to mention the fortunate environment and opportunities that have attended on his career; opportunities that our country does not afford at this time, but which may be reasonably expected in future among a people so intensely practical, because on all hands there is evidence that education and effort are being especially directed to the natural sciences, and this must in the end lead in the National economy to some form of recognition for those who, like Lord Kelvin, set out to work in the interests of all men, and of human progress, irrespective of nation, creed, or race.

It is a pleasure to feel there is one plane on which people of all nations can meet in the spirit of a common cause, divested of jealousy and that false patriotism that denies the fraternity of civilized people—the plane of science. This feeling, one of the noblest of human attributes, coupled with the interests of commerce, are almost the only forces that restrain people from the barbarism of war.

I cannot remember that Lord Kelvin has ever directed his energies to the improvement of implements for destruction. It is scarcely conceivable that he would do so in the absence of logic or philosophy for killing people and destroying property to determine problems of international polity as they arise at this day. I am proceeding on inference in this matter, and in the thought that next to being an expression of regard for Lord Kelvin's labors, the principal fact of this meeting is its international or denational character.

Thermo-dynamics being closely allied with the mechanic arts, and consequently with commercial interests, cannot claim the liberal nature of some other branches. Foremost in this spirit is the medical profession. It is strange that there is scarcely one among those who have in recent times risen to eminence in scientific research that have not taken a medical degree at the beginning of their career. Liebig, Huxley, Mayer, Leibnitz, Faraday, Tyndall, Helmholtz and Thomson, have all, as I believe, drawn inspiration from the universality of medical science.

This admission, we of the useful arts are glad to make, pointing out, however, that the example of Lord Kelvin's career shows the unselfish nature of all scientific pursuits by men of broad views and intelligence to see the interdependence of all human interests.

The product, to so call it, of the University of Glasgow is a national anomaly. Out of the bigotry and intolerance of Scotland in the seventeenth century, came

advanced and liberal ideas in both science and economics in the nineteenth. In 1776, Adam Smith published the "Wealth of Nations," which Thomas Buckle claims has influenced the affairs of mankind more than any other book, the Bible alone excepted.

Circumstances point to a revulsion there against what was not proved or provable, and the exact sciences took root in that old school at Glasgow, producing among many other men of eminence, most notable of all, the one in whose honor this meeting is held.

The Civil Engineers' Club of Cleveland.

MEETING of the Civil Engineers' Club of Cleveland at the Club rooms in Case Library, June 9, 1896. President Howe in the chair.

The minutes of the last two meetings were approved. The application of Mr. Virgil G. F. Marani, for admission to active membership, was read. Messrs. C. W. Hopkinson and C. O. Palmer were appointed tellers to canvass the ballots for membership of Elmer A. Sperry.

Dr. C. O. Arey then presented the paper of the evening upon "Water Supply and Sewerage as affected by the lower vegetable organisms."

The Doctor in his exhaustive and interesting paper considered the subject in sections, as follows:

(1) Water contains few bacteria that are harmful.

(2) All water contains forms of life that destroy bacteria.

(3) Sunlight destroys bacteria.

(4) Water will purify itself when the source of contamination is removed.

(5) Sewer-gas alone is not dangerous to health.

(6) The effect of disease organisms upon water supply and upon sewage disposal.

He showed how imperfect were ordinary filters as precautions against the germs of disease in water; how they served as breeding-places for the same under the usual conditions and management; how little reliance could be placed upon the clear, sparkling appearance of drinking-water as an indication of its purity; and how difficult it was to avoid the germs of disease. On the other hand, he also testified to the little danger incurred by a healthy person in drinking-water as it is usually found; and how little danger there was in the ill-smelling sewer-gas.

Interesting questions from Messrs. Warner, Hopkinson, Porter, and others brought out many facts that showed the errors of current notions in regard to danger from typhoid and cholera germs.

The discussion also brought out the fact that there is no efficient inspection or means provided to prevent the use of the public sewers of this city for typhoid or cholera infected excretia.

The President announced the election of Mr. Sperry. The members of the Club then adjourned to the restaurant.

F. A. COBURN, *Secretary.*

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